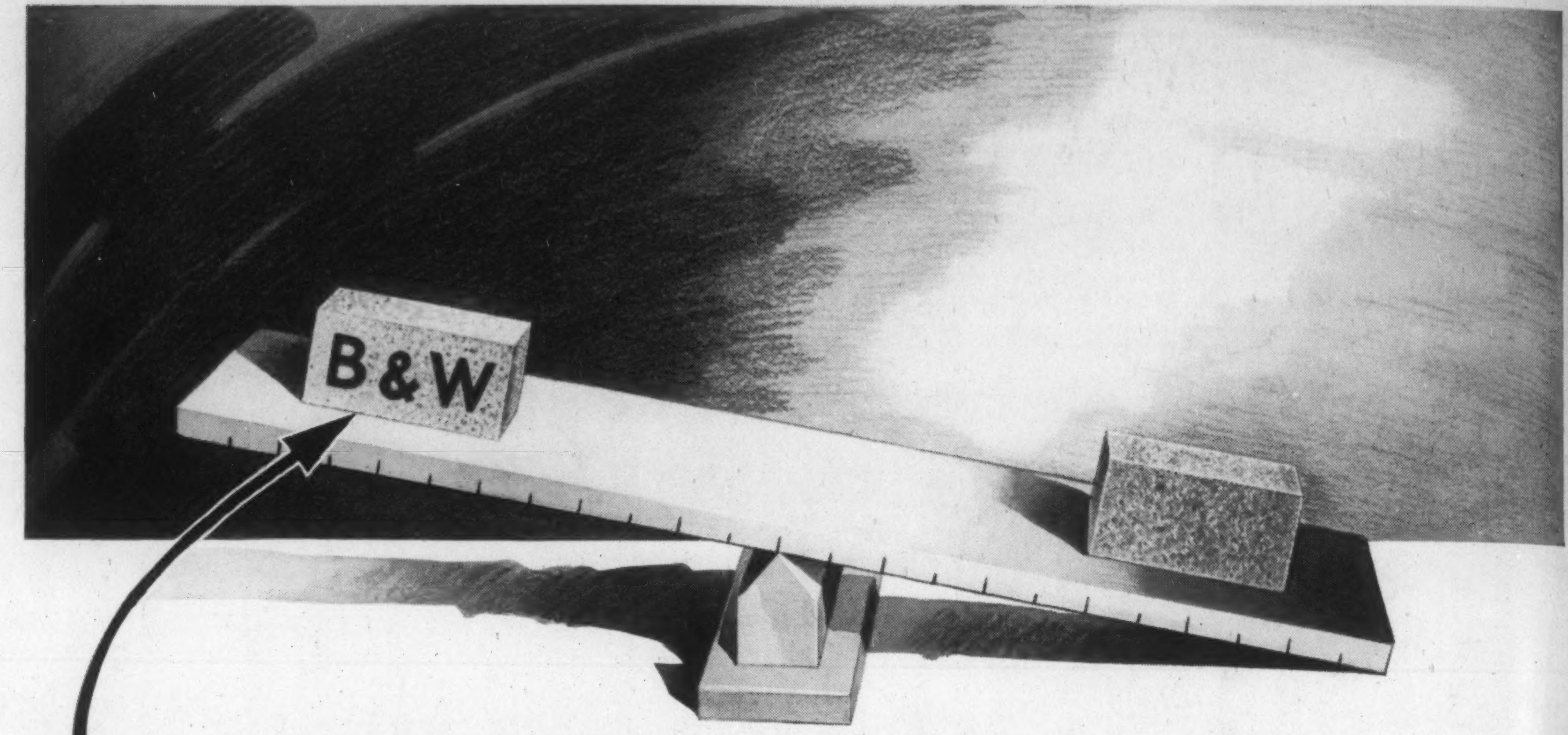
Metals and Alloys

THE MAGAZINE OF METALLURGICAL ENGINEERING

PRODUCTION · FABRICATION · TREATMENT · APPLICATION

APRIL 1941



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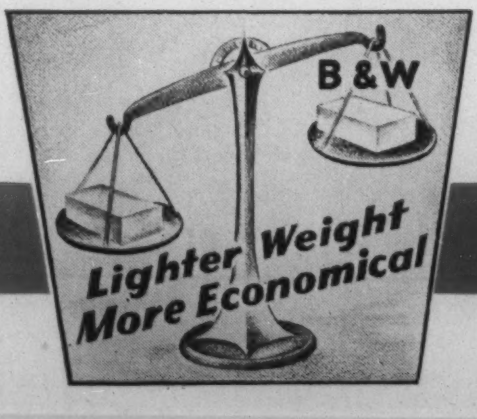

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Metals and Alloys

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Whether you're building
GUNS, TANKS,
FIGHTING
PLANES*
ROLLER BEARINGS,
WRENCHES,
...or TRUCKS*

highlights

Feature Section

Steel and Iron in the U. S. S. R.

The trends and experiments in making pig iron and steel in the U. S. S. R. will bear careful watching, says Mr. Case. He points out some interesting and significant developments which have been in progress in the last 10 years.

Electrolytic Polishing

The relative merits of electrolytic and mechanical polishing of steel specimens for metallographic examination are discussed by authorities in this field. The electrolytic method is applicable to both carbon, alloy, and stainless steels, and when properly carried out assures polishing of a high order.

Metallography of Stainless Steels

The series of articles on the practical metallography of the stainless steels by Mr. Watkins is concluded in this issue. The reaction to this presentation has been highly satisfactory.

Tin Coatings on Steel

Some very interesting and beautiful photomicrographs of cross sections of light tin coatings on steel are presented by Messrs. Romig and Rowland. It is believed that many of these have not been shown previously in the literature. The general subject of the metallography of tin coatings is discussed.

Hydrogen in Steel and Cast Iron

The pressure of hydrogen in steel or cast iron has certain definite effects on the vitreous enameled coatings on these materials. Many phases of this interesting subject are discussed by Messrs. Zapffe and Sims in this, the first installment of a ful treatment of the subject.

Age-Hardenable Hardfacing Alloys

Surface hardnesses of 65-67 Rockwell C are attainable in certain "low-carbon" cobalt-iron hardfacing alloys, containing beryllium and molybdenum, through an age-hardening treatment, reports Ehlers (page 494).

Engineering Digests

Desulphurizing European Pig Iron

European methods for desulphurizing pig iron are reviewed by Evans (page 468). The use of sodium carbonate is evidently widespread, particularly in Germany and England. A British trend is noted toward the application of soda ash desulphurizing to acid as well as basic irons.

Air-Conditioned Bessemers

One of the aims of blowing dried air through basic Bessemer converters—now being investigated in Germany by Eilender and Veit (page 490)—is to cut down the amount of hydrogen absorbed by the molten metal and give a sounder steel. Other advantages cited are the permissible use of larger scrap additions and of lower-phosphorus pig.

Welding-Electrode Coatings

Some of the things arc welding fluxes are expected to accomplish and their actual utility for manual and automatic welding are reviewed in a composite digest on page 476.

Induction Stress-Relieving Preferred

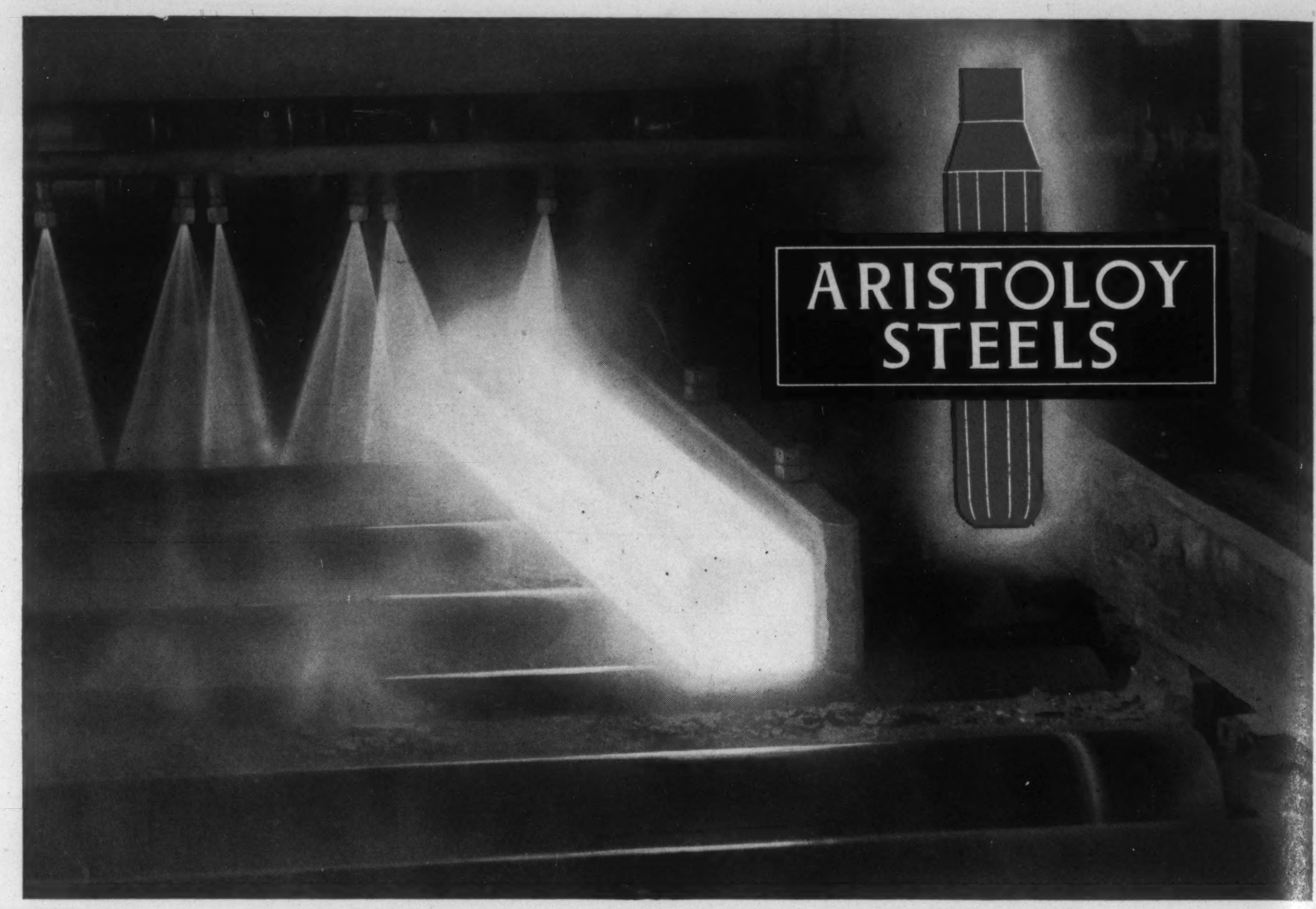
According to Ronay (page 484) induction heating is preferable to indirect heating in an atmosphere furnace and to direct-resistance heating for stress relief of welded naval piping.

Indium Plating

With indium-plated bearings getting a lot of industrial attention, it's timely to have a description by Linford of indium *sulphate* plating baths using a combination of soluble and insolube anodes to keep pH within optimum limits, and by Dyer of the conventional *cyanide* bath—all in a "composite" on page 486.

Metals in the Cold, Cold Air

The effect of low temperatures on the properties of several aircraft metals is investigated by Rosenberg (page 494). The austenitic stainless steels and nickel-base alloys are shown to be stratospherically ideal.



OPEN HEARTH ALLOY STEELS:

BARS — Hot Rolled, Annealed or Normalized, Spheroidized Annealed, Heat-Treated, Cold Drawn, Straightened, Turned, Centerless Ground.

ELECTRIC FURNACE ALLOY STEELS:

BLOOMS, BILLETS, BARS — Hot Rolled, Annealed or Normalized, Spheroidized Annealed, Heat-Treated, Cold Drawn, Straightened, Turned, Centerless Ground.

ARISTOLOY S.A.E. ALLOY BILLETS AND BARS; OXIDATION AND CORROSION RESISTING STEELS; TOOL AND SPECIAL STEELS; AIRCRAFT QUALITY STEELS; STAINLESS STEELS

COPPERWELD STEEL COMPANY · WARREN, OHIO

editorial

Substitutes

This is one of those topics in which the detailed situation may change before comment can be printed. Nevertheless, certain generalities seem certain. Some change will come about in the use of metallurgical raw materials as a result of official urging to use substitutes, and the establishment of definite priorities on some metals of which there is possibility of temporary shortage.

As this is written, aluminum, magnesium, zinc, tungsten and nickel are on the list of materials that are restricted, either by official action or by the condition of the market, from industrial non-defense uses. Oddly enough, of these, only tungsten is normally carried on the "strategic" list. Of all these, there is, either here or in Canada, ample ore (though much of the domestic bauxite and some of the tungsten are low grade, usable only after expensive purification), and there is complete technical knowledge available on the reduction of the metals. It is straight engineering to expand mining and refining. Yet even these old stand-bys need to be conserved, and substitutes utilized.

In view of the availability and suitability of molybdenum for high speed tools, tungsten is probably the least of the worries. Aluminum for pots and pans is scarce, but the housewife can generally fall back on her reserve supply of dented ones so that the scarcity will fall hardest on the newly-weds. Perhaps showers of old, reconditioned aluminum ware will become fashionable.

The suggested substitution of plastics for aluminum washing machine agitators, for magnesium housings for vacuum cleaners, and for decorative zinc base die castings in automobiles is extremely interesting. And when the excess capacity for aluminum, magnesium and zinc is released, and these come back into competition with plastics, the struggle will be even more interesting. Some commentators "fear" that permanent replacement of metals will occur, but they might better be pleased at the prospect of actual experience in the use of a variety of materials from which all the raw materials will the more rapidly shake down into their own "supremacy areas." If a plastic is a more satisfactory material for a given use, and if the present situation leads to such a cheapening of plastics that they can displace metals, those matters are all right. Such use should go far to make more apparent how real the alleged need for ductility and toughness is in many parts where toughness is now demanded. Plastics, in spite of their name, are pretty brittle at the temperature of use. Where plastics serve, brittle alloys may sometimes serve equally well and limitations in the use of many cheap, corrosion-resistant, but rather brittle alloys may be removed through such experience.

Substitution for galvanized steel could have interesting angles. A paraffined paper bucket used as a garbage can and carted away with its contents might be as acceptable as the regulation galvanized can.

The present situation as to nickel is the first thing in which we have had to face the problem that has long confronted Germany, of finding substitutes for nickel steels and nickel cast irons. Scores of German articles have been written to show that nickel steels, on the basis of a few standard laboratory tests, are replaceable. Indeed, the over-all impression one gets from the plethora of anti-nickel Nazi articles is that "the lady doth protest too much." If nickel steels are so firmly entrenched as to need so much argument over their replaceability, they are quite evidently very good stuff. Such matters as the convenience of their lower heat-treating temperatures are not brought into the German discussions. While it is correct that the finished part may often be as serviceable when made of a competing steel, and this competition may bring about some degree of permanent replacement, it seems likely that when nickel is again widely available, it will again regain most of its standing as an alloying element for steel. In cast iron, the shortage of nickel may bring about more in the line of permanent replacement, since more knowledge about late additions of silicon, or of various proprietary silicon-containing alloys, and about the use of copper instead of nickel, might result in a swing away from nickel for making ordinary high test iron and put it more in the position of a material to be reserved for addition to nickel-free high test iron when it is necessary to produce a super-iron.

The thoughts of Government authorities seem hitherto to have been confined to stock-piling and to the problems of utilization of low grade domestic

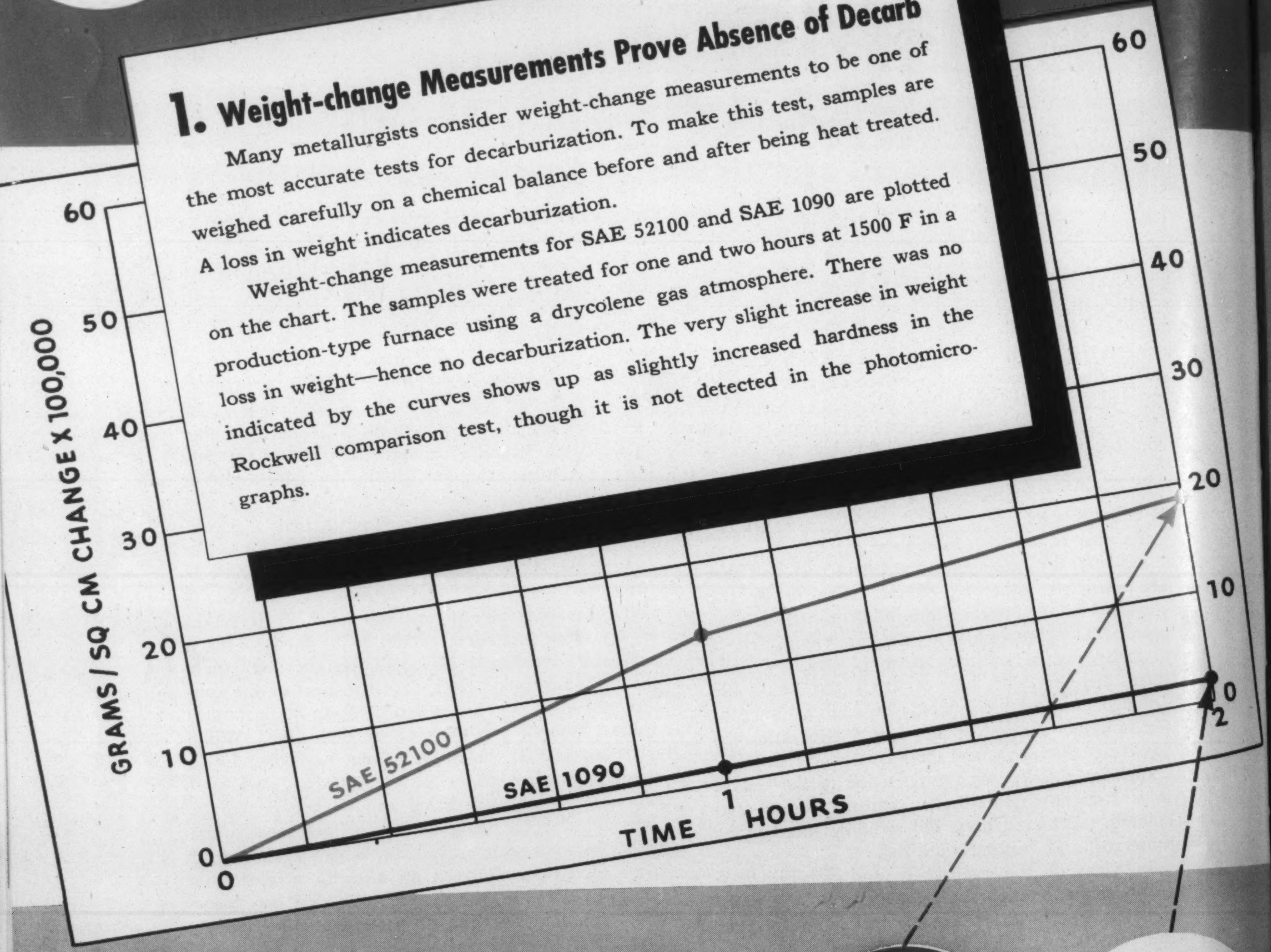
(Continued on page 448)

3 Tests Give Conclusive Proof— S

1. Weight-change Measurements Prove Absence of Decarb

Many metallurgists consider weight-change measurements to be one of the most accurate tests for decarburization. To make this test, samples are weighed carefully on a chemical balance before and after being heat treated. A loss in weight indicates decarburization.

Weight-change measurements for SAE 52100 and SAE 1090 are plotted on the chart. The samples were treated for one and two hours at 1500 F in a production-type furnace using a drycolene gas atmosphere. There was no loss in weight—hence no decarburization. The very slight increase in weight indicated by the curves shows up as slightly increased hardness in the Rockwell comparison test, though it is not detected in the photomicrographs.



2. Hardness Comparison Shows No Decarb

The Rockwell hardness comparison is an accurate test that can be quickly and easily made on regular production samples. For this test, a Rockwell "C" reading is made on a sample of heat-treated steel. Then a Rockwell 15N "Superficial" reading is made on the same sample. The "Superficial" reading is converted to the "C" scale. If the converted reading is greater than the direct "C" reading, there is no decarburization.

The Rockwell "C" and converted "Superficial" readings shown were made on the same samples used for the weight-change measurements. Note that the converted "Superficial" readings (N) are slightly greater than the "C" readings—indicating that no surface decarburization has occurred.

C-66.8
N-68.6

C-66.5
N-66.8

C = Rockwell "C" hardness (150 kg load)

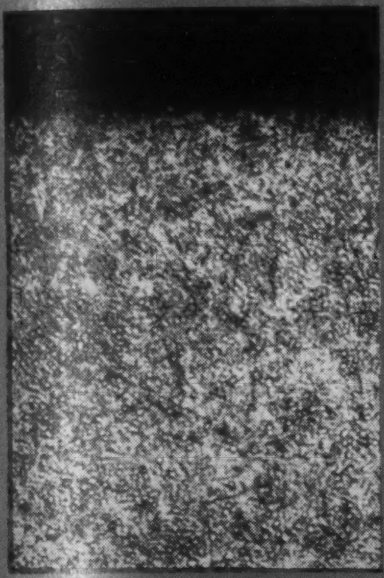
N = Rockwell 15 N "Superficial" hardness (15 kg load) converted to "C" scale

Steels Treated in Drycolene Show NO DECARB

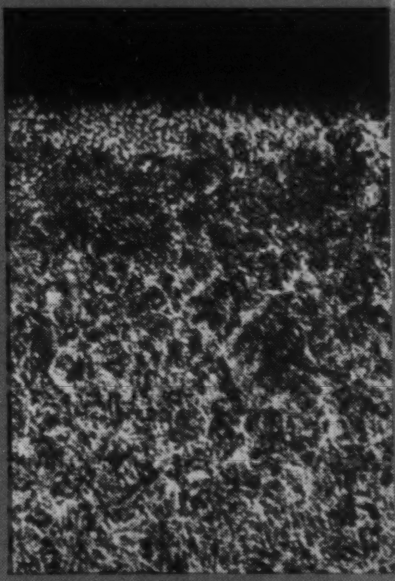
3. These Photomicrographs* Give More Proof

HARDENED IN DRYCOLENE

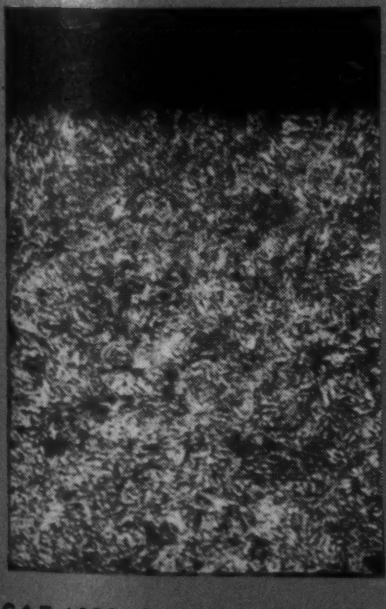
HARDENED IN PARTIALLY CONVERTED GAS



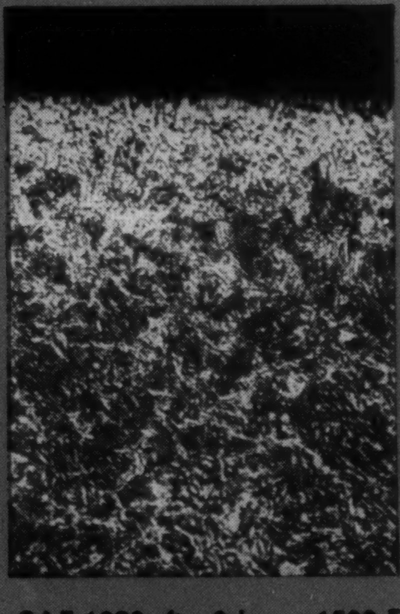
SAE 52100 after 2 hours, 1500 F, in furnace using drycolene as a protective atmosphere. Absolute uniformity of structure extending to surface is proof of no decarburization—no soft skin.



SAE 52100 after 2 hours, 1500 F, in furnace using partially converted gas as protective atmosphere. The white band at the surface indicates carbon-free ferrite and is proof of decarb.



SAE 1090 after 2 hours, 1500 F, in furnace using drycolene atmosphere. Structure is uniform—not a trace of decarb.



SAE 1090 after 2 hours, 1500 F, in furnace using partially converted gas as protective atmosphere. The depth of the white, ferrite-rich band indicates more severe decarb than in SAE 52100.

*Originals at 500 ×. Picral etch

HERE are the results of three separate tests for decarburization on SAE 1090 and SAE 52100 steels that were heat-treated in a drycolene protective atmosphere. All three—weight-change measurements, Rockwell hardness comparisons, and photomicrographs—lead to the same conclusion. *Even fussy steels won't decarburize during heat treatment if drycolene is used as the protective atmosphere.*

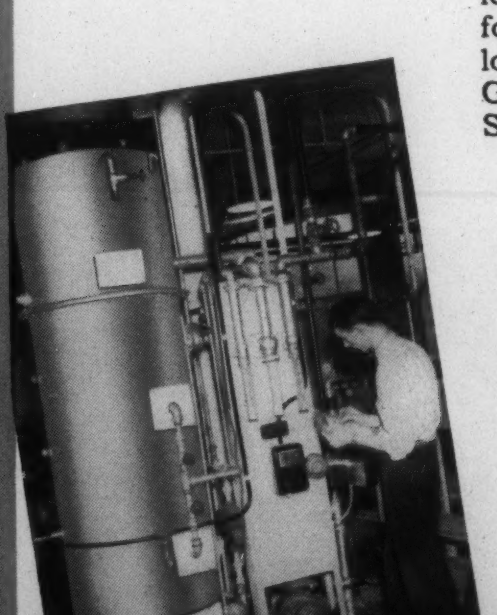
What Is Drycolene?

Drycolene is a balanced blend of gases, principally CO and N_2 with some H_2, for use as a protective atmosphere in heat-treating furnaces. It contains no oxygen, moisture, or carbon dioxide—the principal decarburizing agents. Hence, no decarburizing reaction can take place between the atmosphere and the steel. Parts treated in drycolene are clean, bright, and hard right to the surface. There is no softening or other surface deterioration requiring expensive machining operations for removal.

Where You Can Use Drycolene

Because high-carbon steel parts treated in drycolene are free of scale, as well as decarburization, it is an ideal atmosphere for scale-free hardening, bright-annealing, and copper-brazing furnaces.

A new publication, GEA-3525, gives complete information about drycolene and about equipment for producing it. Ask our local office for a copy. General Electric Company, Schenectady, N. Y.



Complete self-contained unit produces drycolene at low cost

This G-E drycolene producer, rated 750 cfh, will dependably supply drycolene at a cost of from 16 to 57 cents per thousand cubic feet, depending on local prices of raw materials. This equipment will process either city gas, natural gas, or propane.

GENERAL ELECTRIC

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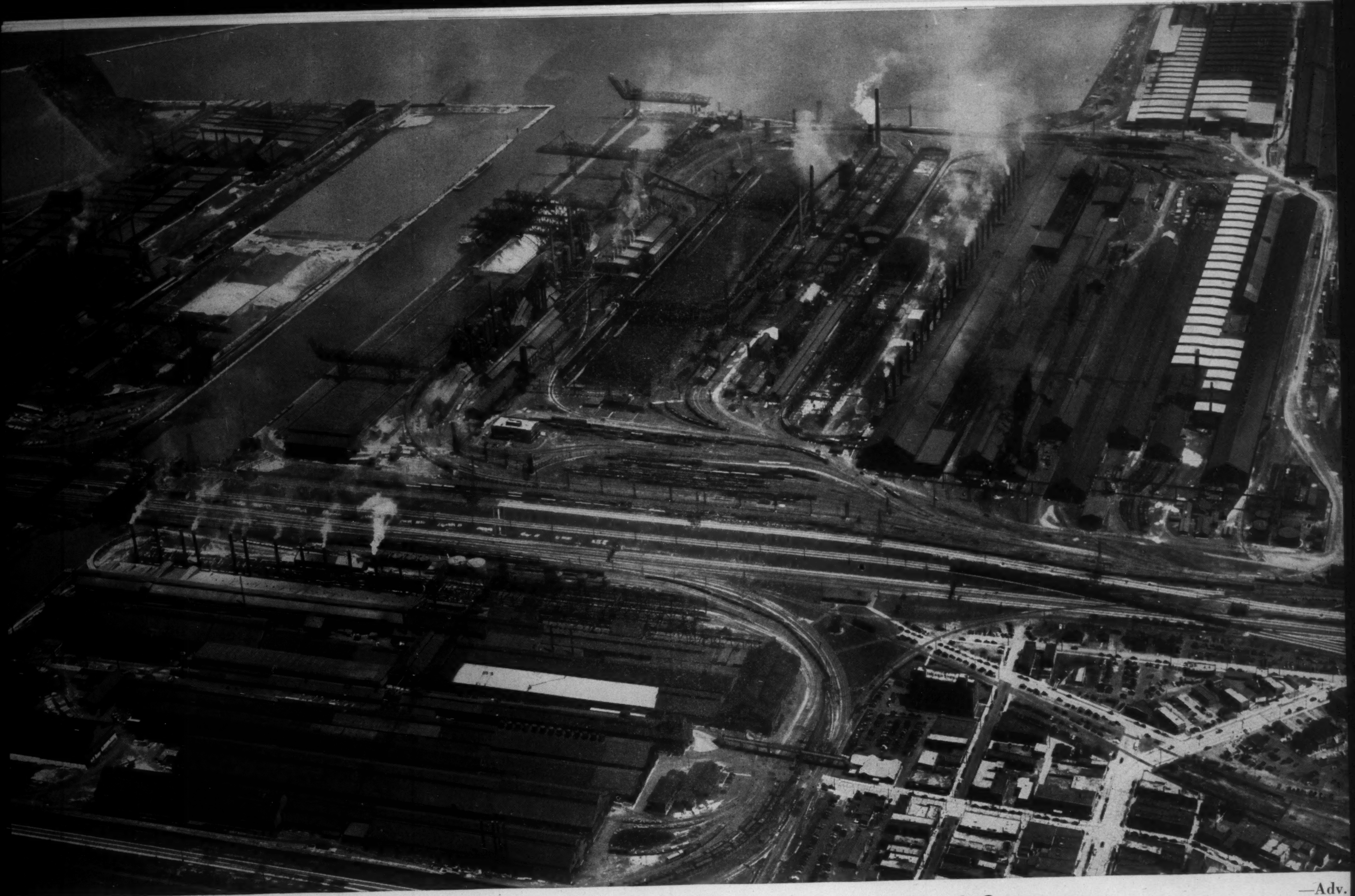


Airplane View of the Principal Plant of Inland Steel Company

This aerial photograph, taken at an altitude of 1,000 feet, shows the Indiana Harbor Works, on the south shore of Lake Michigan. The No. 1 unit, and the administration building, are in the foreground. Across the tracks is the No. 2 unit, with the 76-in. and the new 44-in. continuous sheet and strip mills at the right. The capacity of this modern plant has been increased 40 per cent in the last eight years.

—Adv.

TRENDS AND EXPERIMENTS IN

Making Steel in the U. S. S. R.

A CORRELATED ABSTRACT

by S. L. CASE

Metallurgist, Research and Development Division, Jones & Laughlin Steel Corp., Pittsburgh.

The author has reviewed in this article the highlights of research in iron and steel during the last 10 yrs. in the U. S. S. R. He says that research in that country, although it displays impetuosity and a certain degree of exhibitionism, will bear watching.

Mr. Case discusses both blast furnaces and open-hearth developments. Of interest to blast furnace men is the use of "ferrocoke" and the addition of steam to the blast. Open-hearth operators will read with interest the references to petrographic slag control, effect of the thickness of the mold, and so on.
—The Editors

A BETTER UNDERSTANDING of the driving force behind many of the articles appearing in various technical publications of the U. S. S. R. may be had if one bears in mind that the upper right corner of the front page in every issue is reserved for the clarion call: "Proletarii vsiekh stran, soedinyaites!" or literally "Proletarians of all lands, unite!" An editorial quoting excerpts from Roosevelt's third inaugural address might seem somewhat out of place in a publication like METALS AND ALLOYS, but its Russian contemporaries *Stal* and *Metallurg* quote Stalin oftener than they refer to Gibbs' Phase Rule.

While the propaganda angle of many U. S. S. R. technical articles cannot be lightly dismissed, it should be borne in mind that since the State is the sole owner of industry and employer of labor, research, while not always original, is often carried on on a truly grandiose scale, not being hampered by economic barriers.

Largest Furnaces in the World

As a general statement, the most important problem facing the industry in the U. S. S. R. has been an increase in productivity of the existing plants and design of new and larger plants. It is pointed out with pride in technical publications that the largest blast furnaces in the world, with a capacity in excess of 1300 tons daily, and the largest open-hearths in the world, with a capacity of 400 tons, are in operation in the U. S. S. R. As one of the steps to increase the productivity of the existing blast furnace plants, oxygen enrichment is being experimented with on a fairly large scale. With this end in view a pilot blast furnace has been constructed at the Dniepropetrovsk Steel Works[1] for experimentation with enriched blast under controlled conditions.

Ferrocoke

As another development tending to increase production of blast furnaces at the Stalin Metallurgical Works[2], so-called "ferrocoke" was tried on a large scale in the manufacture of iron. Ferrocoke is the product of an admixture of 10 per cent flue dust to the coal charge in coke ovens. It is reported that 400,000 tons of ferrocoke were thus prepared without introducing any technological difficulties in the operation of the coke ovens, and that the physical quality of the ferrocoke was found to be satisfactory

Pouring a heat of special composition steel from an open-hearth furnace into large ingot molds at the plant of the American Rolling Mill Co., Middletown, Ohio. (Courtesy: American Rolling Mill Co.)

for smooth blast furnace operation. One blast furnace was operated on a 100 per cent substitution of ferrocoke for regular coke, and after a 15-month trial it was claimed that the production capacity of the furnace increased 3.2 per cent, consumption of ferrocoke was 17 per cent lower than that of ordinary coke, and the manufacturing cost of the pig iron decreased 5.6 per cent.

V. Koloskov[3] describes a method for regulation of blast furnace operation by means of an automatic flue dust sampling apparatus, which furnishes a continuous record of the flue dust content in blast furnace gas in grams per liter. By means of a nomograph plotted from observational data it was found possible to vary the coke ratio, pressure, and temperature of blast with the result that the yield of iron increased, silicons were more uniform, and "scaffoldings" were eliminated. F. Chilkevich[4] arrives at the same conclusion on the basis of extended tests. Prof. K. V. Messerle[5] discusses the application of gas analysis to control of blast furnace operations and points out the uncertainties of such control.

Steam Added to the Blast

While the use of dry blast is occupying the attention of American blast furnace men, Russian contemporaries venture in the opposite direction. A. Ryedko[6] describes the operation of a blast furnace on blast containing 5 per cent steam. The steam was admixed with the air under the checkers of the hot stoves and the temperature of the blast was slightly increased. The experiment resulted in an increase of daily production of 12.6 per cent (average daily production with air blast 988 tons of iron; average daily production on steam and air, 1113 tons). This practice is still in use at the Kuznetsk Works.

Y. Smolyanitski[7] reports on the use of blast furnace flue dust in refining pig iron. The flue dust is added directly into the runner during the casting of the iron. A 4 per cent addition of flue dust has shown to increase the pig iron yield 2.5 per cent and to reduce very appreciably the silicon, manganese, carbon, and sulphur contents of the iron. The preliminary refining of the iron was found to increase the production of the open-hearths approximately 15 per cent. It is claimed that the addition of the flue dust does not lower the temperature of the iron.

Increasing Open-Hearth Output

Considerable efforts have been devoted by U. S. S. R. workers to the problem of increasing open-hearth production and in line with this objective the rate of carbon elimination has received particular attention. P. Ivanov and R. Katzen[8] have made a statistical study of 939 heats from three different steel works with furnace capacities ranging from 120 tons to 400 tons and a depth of bath from 36 in. to 68 in. It was found that for each type of furnace a definite ratio of $\frac{CaO}{SiO_2}$ gave the highest rate of carbon elimination, but this critical ratio apparently depended on the depth of bath. For the smallest furnace the most favorable ratio was 2.5 and for the largest it was 1.9.

The same study indicated that the thermal capacity of the open-hearth furnace is intimately associated with the rate of carbon drop. It was shown that a 30 per cent boost in heat input increased the rate of carbon elimination nearly five-fold. K. I. Fedorov[9] and S. Levin[10] made a study of the influence of the rate of carbon drop on steel quality. The same subject, as well as a study of conditions controlling the relation of rate of carbon drop and oxygen content of the steel, was investigated by H. Dobrokhotov[11]. The various investigators agreed that a very appreciable increase in rate of carbon elimination may be attained without adverse effect on steel quality. The so-called Stakhanov method of speeding up the open-hearth steel making was based on these studies and is now in general use in U. S. S. R. as shown by a series of articles on this subject.

Petrographic Slag Control

In an approach somewhat similar to that used by E. C. Smith[12], in the United States, P. Umrikhin and V. Lapin[13] propose a petrographic slag control method for the open-hearth. The authors claim that, with their method, a thin section of the slag sample may be prepared in 15 min. and the petrographic identification of the slag may be made in 5 to 10 min. The examination may be facilitated by preparing instead a finely powdered slag sample immersed in a liquid of known refractive index. Slag tests are to be taken at four different periods of the refining stage with the idea of controlling the quantity of either lime or bauxite additions required to give the most satisfactory type of slags.

A rapid method for estimation of the degree of oxidation of the bath is proposed by V. Zamoruev.[14] A small number of cast iron cups with a capacity of 750 grams of steel each are placed next to the furnace. An 0.05 gram of aluminum is placed in the first cup; 0.1 gram, 0.2 gram, 0.3 gram, etc. are placed in the consecutive cups. These cups, kept at the same temperature, are filled with molten metal from a spoon. Generally the metal is killed in some of the cups and not in others, so that a workable indication of the degree of oxidation of the bath is thus obtained. From a number of such tests empirical graphs have been worked out and have proved useful for routine open-hearth control.

Another investigator, A. Samarin[15], describes a method for gas analysis on bath samples taken at various stages of the refining period. The method is similar to the one described by Hare, Peterson, and Soler[16] in the United States. One end of a steel pipette previously evacuated is immersed in a spoonful of molten metal. Gases liberated during freezing of the metal sample trapped in the pipette are removed through a suitable valve to a gas analyzer. It is claimed by Samarin that a bath test may be completed in less than 20 min. and that the results are fairly reproducible.

Preliminary Refining in Large Furnace

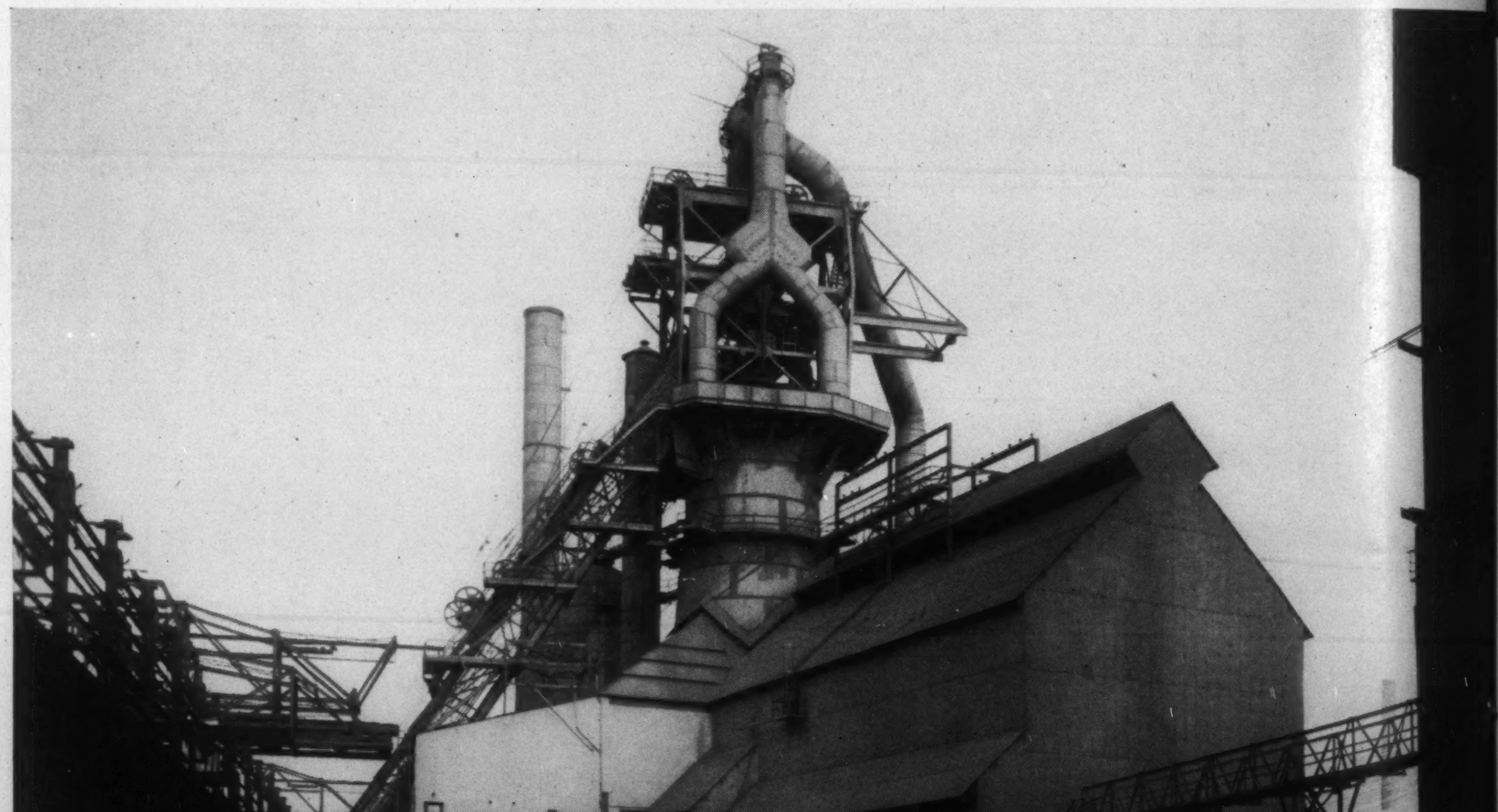
In line with the "Stakhanov" or speed-up trends in steel making N. Dobrokhotov[17], a member of Leningrad Academy of Sciences, gives constructional details of a method for steel making in which the preliminary refining is carried out in a continuous oxidizing furnace of large capacity (1440 to 2880 tons per day). Approximately 125 tons of iron are charged into this furnace every 1 or 2 hrs.; ore, limestone, and bauxite preheated to 2200 deg. F. enter the oxidizing furnace in a continuous stream from a rotating cylindrical furnace. This furnace, somewhat similar in design to a Brackelsberg furnace of large capacity, is heated by the combustion products of the oxidizing furnace. From the oxidizing furnace the semi-finished metal is passed through a runner into a refining furnace located at a lower level.

Effect of Mold Thickness

An interesting study of the influence of mold thickness on rate of solidification of ingots was made by I. Granat[18]. Ingots were cast in round eccentric molds in which the wall thickness ranged from a low of 3.2 in. to a high of 9.6 in.; the diameter of the mold was 26 in. and the height 92 in. By means of inserted thermocouples, temperature measurements were made of the solidifying ingot at certain distances from the thinnest as well as from the thickest section of the mold wall. The solidified ingots were split longitudinally for structural examination.

One of the conclusions of this study was to the effect that, while a thicker mold wall assists the

Inland Steel Co.'s new 1,000-ton per day blast furnace lighted about two years ago. (Courtesy: Inland Steel Co.)



The Bethlehem Steel Co. recently tapped the first heat from this new 190-ton open-hearth furnace. It was built in less than three months after construction was commenced. It is the largest of its type at the company's Bethlehem, Pa. plant. (Courtesy: Bethlehem Steel Co.)

formation of a thicker skin zone on the ingot in the first stages of freezing, it retards the further stages of solidification. This phenomenon is explained by the fact that, at a certain critical mold wall thickness, the balance between quantity of heat abstracted from ingot by mold wall and the heat transmitted by radiation and convection from mold to atmosphere shift in favor of the thinner wall. As a practical conclusion from this study it was recommended that, contrary to generally accepted practice, wall thickness should be greatest at the top of the mold and that mold taper should be held to an absolute minimum necessary for stripping. It was suggested that a definite advantage may accrue from the use of thinner mold walls for many applications.

This abstract of necessity has touched only the highlights of iron and steel research carried on in U. S. S. R. during the past decade. Compared with that of continental Europe, England, and the United States, Russian research seems to display more impetuosity and a certain degree of exhibitionism; however, the fact that immediate economic considerations are no barrier to long term research may prove to have an important bearing on the future status of technical developments in the U. S. S. R. and these will bear watching.

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Electrolytic Polishing

by G. F. MEYER, G. D. RAHRER and J. R. VILELLA

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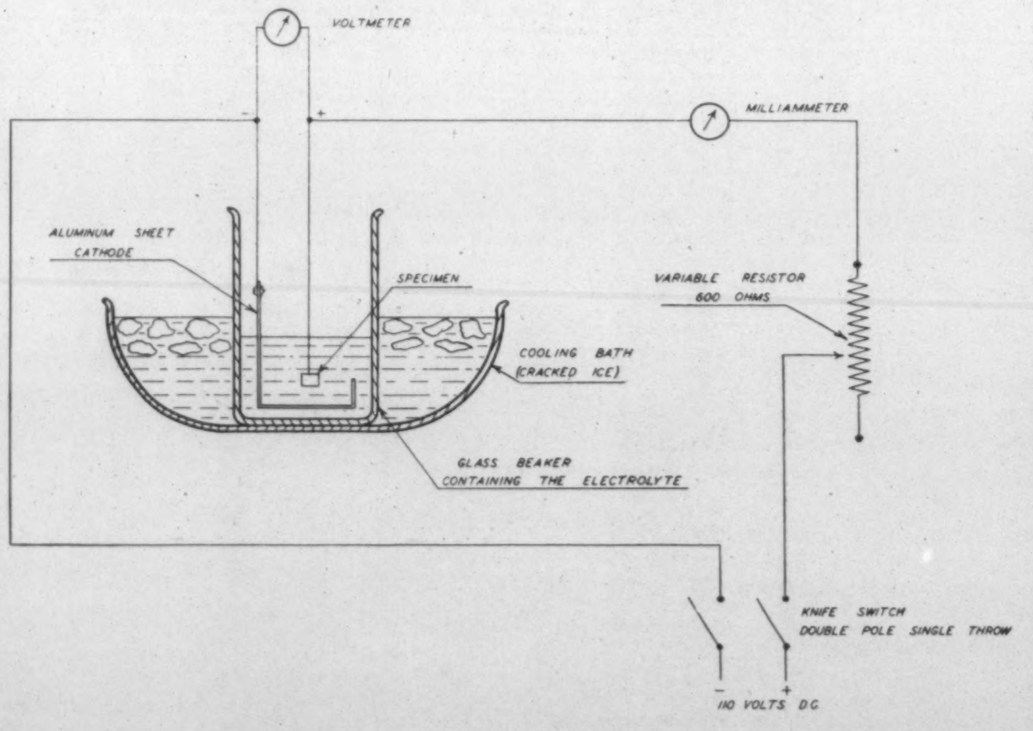
Polishing steel specimens for microscopic examination is always a difficult as well as a painstaking task—the polishing must be of a high order to assure efficient examination. The mechanical method is the one most generally used. But the authors of this authoritative article not only describe an electrolytic method and how to use it, but also state that specimens of low carbon or low alloy steels can be polished electrolytically with a degree of perfection comparable to that obtainable by competent mechanical polishing. They also assert that ferritic and austenitic stainless alloys can be polished electrolytically with a degree of perfection difficult to attain mechanically.—The Editors.

THE METHOD OF ELECTROLYTIC POLISHING originated by Jacquet and Rocquet[1] and later discussed by Pellissier, Markus and Mehl[2], has been tested on a considerable number of plain carbon, low alloy and stainless steels, and the results compared with those obtained by the mechanical polishing procedure we have been using. This consists of grinding on a series of three lead laps using natural emery as abrasive and finishing with levigated alumina on a special grade of cloth; the emery powders used are grades Nos. 302, 303½, and 305 purchased from the American Optical Co. The mechanical method in skillful hands yields a polished surface of a high order of flatness with comparatively small distortion of the surface metal and with excellent preservation of the non-metallic inclusions. In some respects the electrolytic method compares very favorably with the mechanical method and in other respects it is inferior; indeed the methods supplement each other and therefore both should be available in the metallographic laboratory. Our experience leads us to the following general conclusions:

Fig. 1. Wiring diagram for the electrolytic polishing.


VOLTMETER
MILLIAMMETER
ALUMINUM SHEET CATHODE
SPECIMEN
VARIABLE RESISTOR 600 OHMS
COOLING BATH (CRACKED ICE)
GLASS BEAKER CONTAINING THE ELECTROLYTE
KNIFE SWITCH DOUBLE POLE SINGLE THROW
110 VOLTS D.C.
-
+

General Conclusions

1. Specimens of plain carbon or low alloy steel, intended primarily for examination of their microstructure, can be polished electrolytically with a degree of perfection comparable to that obtained by competent mechanical polishing. Polished surfaces practically free from distortion of the surface metal, free from scratches and sufficiently flat and smooth for examination at all magnifications are obtainable. A variety of steels, ranging in carbon content from a trace to 1.80 percent, composing practically all the microstructures common to these steels, were electropolished satisfactorily.

2. Electrolytically polished surfaces may exhibit certain defects, of which the most frequent are: (a) an undulating, rather than a plane, surface, (2) high relief of the carbide particles, particularly when they are coarse, as in spheroidized structures, and (c) attack on the non-metallic inclusions. The waviness of the polished surface and the relief effect of the carbide particles, if kept to a minimum, do not interfere seriously with the proper development of the structure by etching, or with its microscopic examination; but the attack on the non-metallic inclusions is excessive, particularly in low carbon steels, and makes the metal appear considerably "dirtier" than it actually is. In this respect the electrolytic method yields results inferior to competent mechanical polishing.

3. No time or effort is saved during the grinding part of the polishing procedure because to obtain optimum results by the electrolytic method the specimen must be ground to the same fineness as for mechanical polishing. In general, the finer the grinding, the shorter the time needed to produce a satisfactory polish, the less the waviness and relief effect, and the less the attack on the non-metallic inclusions. Time can be saved in imparting the

# of Steel Specimens

final polish when (a) the specimens are unusually large, (b) when an excessive amount of disturbed metal is produced during the grinding part of the process, and (c) when the operator is unskilled at mechanical polishing. In mechanical polishing, the length of time required to impart the final polish increases rapidly with the size of the specimen, but in electropolishing size makes no difference, provided that the necessary current density can be obtained. In mechanical polishing it is often necessary to repolish, re-etch and examine the structure microscopically several times in order to be certain that all traces of disturbed metal have been eliminated; this often consumes considerable time. In electrolytic polishing, on the other hand, it is often possible to dissolve all disturbed metal by a single treatment. The time required to finish a specimen correctly by mechanical means depends to a great extent on the skill of the operator, but in electropolishing the skill of the operator is a less important time-saving factor, since he only has to calculate the current needed to produce the required current density, adjust the circuit, and agitate the electrolyte while the specimen is in it. The time generally consumed to polish electrolytically after the specimen has been ground to the required fineness is approximately 10 minutes. A skillful operator can finish a specimen of average size mechanically in shorter time.

4. It has been reported[3] that the electrolyte (a solution of perchloric acid and acetic anhydride) is violently explosive and must, therefore, be handled with extreme care at all times. Contamination with alcohol and other organic substances is particularly to be avoided. Before anyone attempts to prepare or use these reagents, we strongly recommend that he read the appendix which is a reproduction of the foregoing reference.

5. Specimens mounted in bakelite cannot be electropolished because the electrolyte attacks the bakelite and causes severe staining. In view of the reported explosiveness of the solution it is prudent not to attempt to electropolish any specimen mounted in an organic molding material. The copper strips often used to separate a group of specimens mounted in a steel clamp also cause staining, but specimens mounted in steel clamps without copper strips can be electro-polished using a current calculated on the sum of the area of each specimen plus that of the clamp.

6. Ferritic and austenitic stainless alloys can be polished electrolytically with a degree of perfection that is difficult to attain by mechanical means. For these alloys the electrolytic method appears to be a decided improvement over mechanical polishing, and its adoption for the preparation of stainless specimens is strongly recommended. It constitutes an effective means of eliminating the film of distorted metal produced by grinding, but it tends to leave the non-metallic inclusions in relief, thus exaggerating their size and imparting to the steel an unwarranted "dirty" appearance. This condition can be corrected to a considerable extent by repolishing mechanically.

7. Complete elimination of all traces of disturbed metal is seldom effected by one electrolytic attack of 5 minutes duration; specimens which have been ground on emery or carborundum paper generally require two or three repolishings (electrolytic) and re-etching for total elimination of all traces of disturbed surface metal.

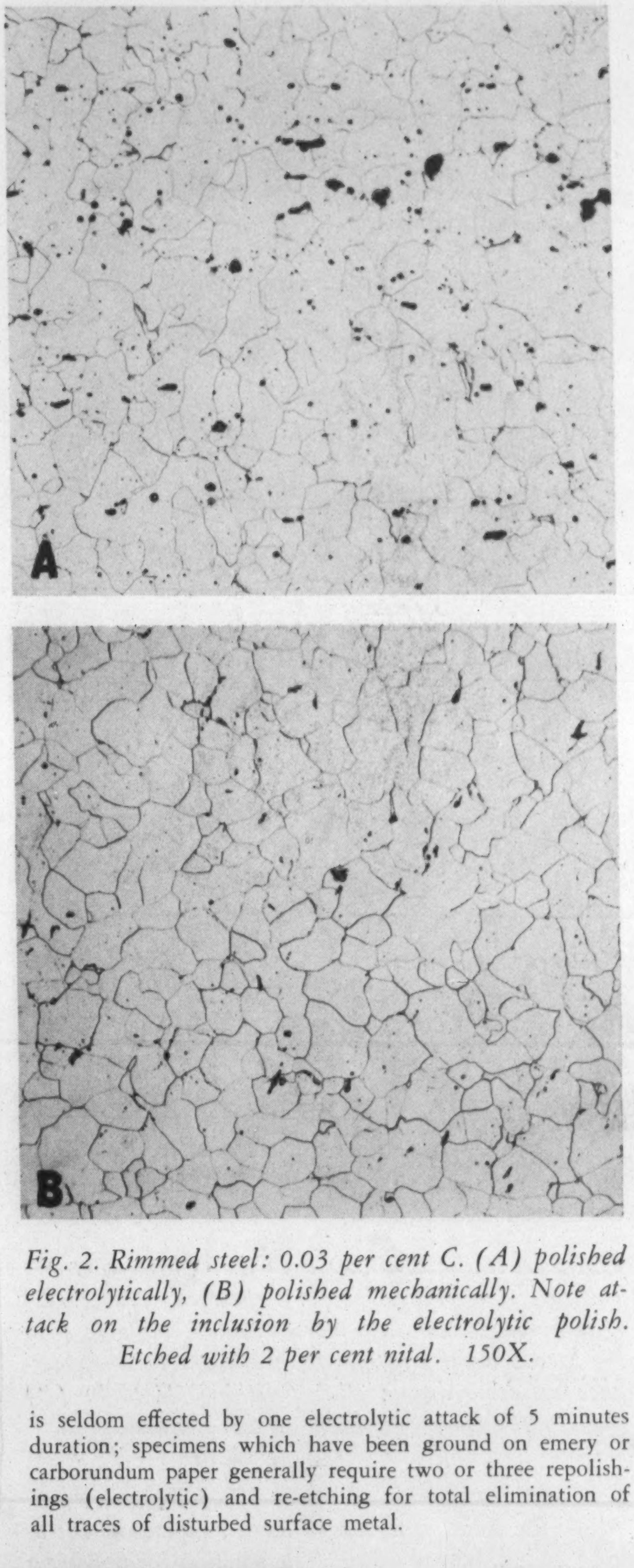


Fig. 2. Rimmed steel: 0.03 per cent C. (A) polished electrolytically, (B) polished mechanically. Note attack on the inclusion by the electrolytic polish. Etched with 2 per cent nital. 150X.

Description of Method

The wiring diagram for the electrolytic polishing apparatus is given in Fig. 1. The electrolyte for polishing plain carbon and low alloy steels is prepared as follows: Place a beaker containing 185 cc of perchloric acid (sp. gr. 1.61) inside of a larger receptacle containing cracked ice, or through which cold water is circulating, and add *gradually* 765 cc

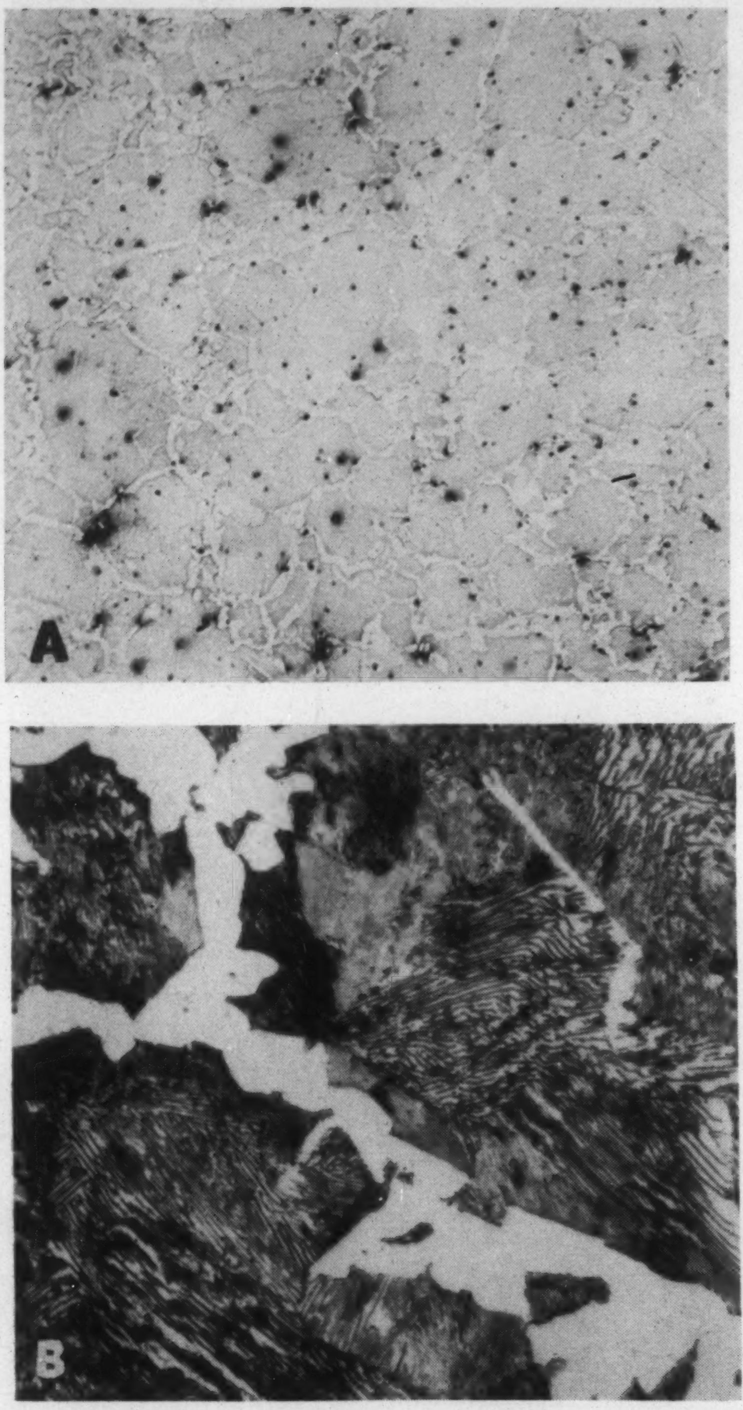


Fig. 3. A steel containing 0.39 C, 0.73 per cent Mn polished electrolytically: (A) unetched, 150X; (B) etched with 4 per cent picral, 1000X. Note in (A) the attack on the inclusions and the etched appearance resulting from relief polishing. Note in (B) the clear definition of the structure.

pure acetic anhydride and then 50 cc distilled water. Allow the solution to rest at room temperature for at least 24 hrs. before using. The solution for polishing stainless steel is prepared similarly but contains 335 cc perchloric acid, 665 cc acetic anhydride and no water. According to the originators of the method it is advantageous to dissolve 0.5 per cent of aluminum, by anodic attack, in the solution for plain carbon steels. This is reported to increase the viscosity of the electrolyte, permitting more vigorous agitation and the use of a smaller current density. Neither electrolyte appears to deteriorate on standing, but both lose potency with use. When it is observed that they are becoming weaker, their original efficiency can be restored by the addition of 1 per cent by volume of water.

The specimen to be polished constitutes the anode of the cell. It should be free from all traces of grease or oil, and any scale present should be ground off before it is placed in the electrolyte.

The cathode can be a sheet of either aluminum, low carbon steel or stainless steel. No effect on the quality of the final polish was observed when the area of the cathode was varied between 10 and 30 times that of the specimen. Likewise, its position with respect to the specimen, whether above, below or to one side, does not seem to influence the final result. A distance of 3/4 to 1 in. between specimen and cathode was found satisfactory.

Proper adjustment of the current density is the factor which, more than any other, is likely to affect the quality of the result. For plain carbon and low alloy steels a current density of 5 amp. per sq. decimeter of total anode surface (approximately 0.3 amp. per sq. in.) is best. If the current density is too low the specimen is likely to be etched deeply and the grinding scratches not removed; if too high, pitting may occur. For stainless steel a minimum current density of 7 amp. per sq. decimeter (approximately 0.45 amp. per sq. in.) should be used; these alloys do not require as careful regulation of the current density as the plain carbon steels, but nothing is gained by using higher current density. The required current for a given specimen is based upon the total immersed area; in the case of a group of thin sheets assembled as a single specimen in a clamp, this total immersed area comprises both the full immersed area of each sheet (both sides) and that of the clamp in addition.

With the current density recommended above, the time required for a satisfactory polish decreases with the fineness of the grinding scratches present on the specimen. In plain carbon and low alloy steels the scratches produced by 500 mesh grit or 000 emery paper can be removed in approximately 5 minutes. Stainless steels similarly ground can be electropolished free from scratches in 4 minutes, but an attack of this duration is seldom sufficient to remove all traces of disturbed metal. Several similar attacks are often needed to accomplish the desired result.

The waviness of the finished surface observed frequently in electro-polished specimens can be minimized greatly by constantly agitating the electrolyte. This may be done either by moving the specimen, by stirring the solution with a rod or other convenient means, or by bubbling air through the solution. Experience has shown that minimum waviness occurs when the stirring is rapid and causes irregular movement of the electrolyte in immediate contact with the specimen.

The sequence of steps in electro-polishing is as follows: After the scale on the sides has been ground off the specimen is ground down to a grit of 500 mesh or finer and all traces of grease removed. Its area is then measured and the current needed to produce the required density calculated. It is then connected to the positive wire (an ordinary battery clamp seems to be adequate) and inserted in the electrolyte, which must be agitated and not permitted to rise in temperature above 85 deg. F. (30° C.) at any time. As the sample is placed in the electrolyte the current is adjusted to the calculated density by means of the rheostat. During the first 20 seconds the current tends to fall and the voltage to rise, this change coinciding with the formation of a reddish-brown deposit on the specimen; while this is taking place the current is adjusted to maintain the calculated density. For the remainder of the attack the current remains constant. When the attack has been completed the specimen is washed free of any deposit and dried; it is then ready for etching.

Discussion of Results

Figs. 2A and 2B show respectively the structure of a low carbon steel polished electrolytically and mechanically. The photomicrograph in each case was considered to be representative of the entire polished surface. Observe that while both structures are equally free from disturbed metal and scratches, the electrolytic method, by attacking the non-metallic inclusions, has greatly exaggerated the apparent "dirtiness" of the steel. Since this is a common occurrence in electro-polished specimens, it is evident that the use of this technique for rating the inclusion content of steel is to be avoided.

Figs. 3A and 3B were obtained from the same specimen of normalized medium carbon steel. Fig. 3A illustrates once again the attack on the inclusions and the amount of etching effect normally present in an electro-polished specimen. The etched appearance is due to relief polishing; in pearlitic steels this relief effect is seldom objectionable because it is not excessive, but in structures made up of coarser carbide particles the difference in level between the carbide particles and the ferrite matrix frequently exceeds the depth of focus of intermediate and high power objectives and thus interferes seriously with microscopic examination and photomicrography. Fig. 3B is an illustration of the clear definition of structure obtainable by electropolishing and subsequent etching with proper technique.

Specimens whose structures were martensite, tempered martensite or bainite were also polished electrolytically with results comparable to those obtained by skilled mechanical polishing. The technique was also found applicable to case carburized specimens.

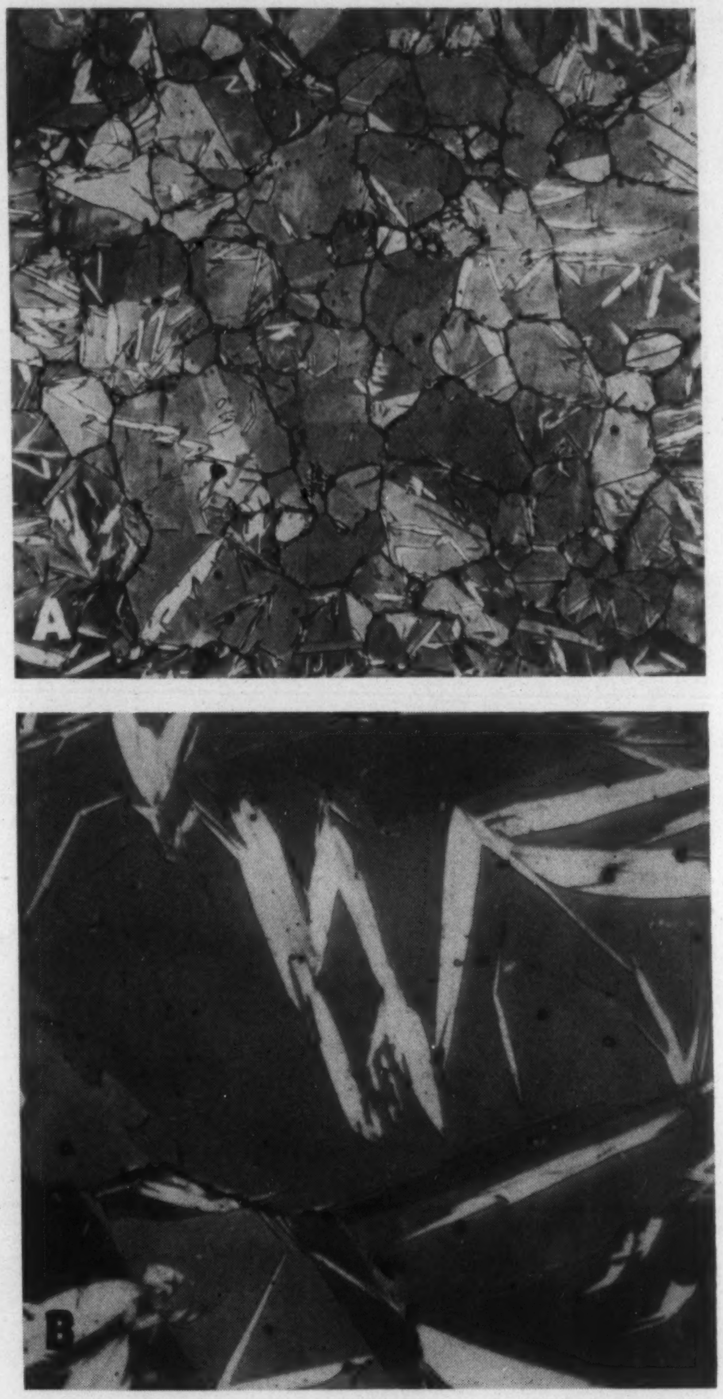


Fig. 4. A 1.80 per cent C steel, quenched in brine from 2000 deg. F.: polished electrolytically. Structure consists of an austenite matrix with carbide at the grain boundaries and some martensite needles. Etched with 4 per cent picral—(A) at 200X; (B) at 2000X.

Our early experiments with electrolytic polishing tended to indicate that the optimum current density differs for steels of different carbon and alloy contents. While for optimum results this is probably true, it is entirely feasible to polish satisfactorily a wide range of plain carbon and low alloy steels using the same current density. Figs. 4A and 4B illustrate respectively the structure of a 1.80 per cent C steel at low and high magnification, which was polished with the same current density used for the low and medium carbon steels shown in Figs. 2A, 3A and 3B. The structure in this case consists of an austenitic ground mass and a few needles of martensite.

The technique for polishing stainless steels recommended by the originators of the method was tested on ferritic iron-chromium alloys containing 12, 17

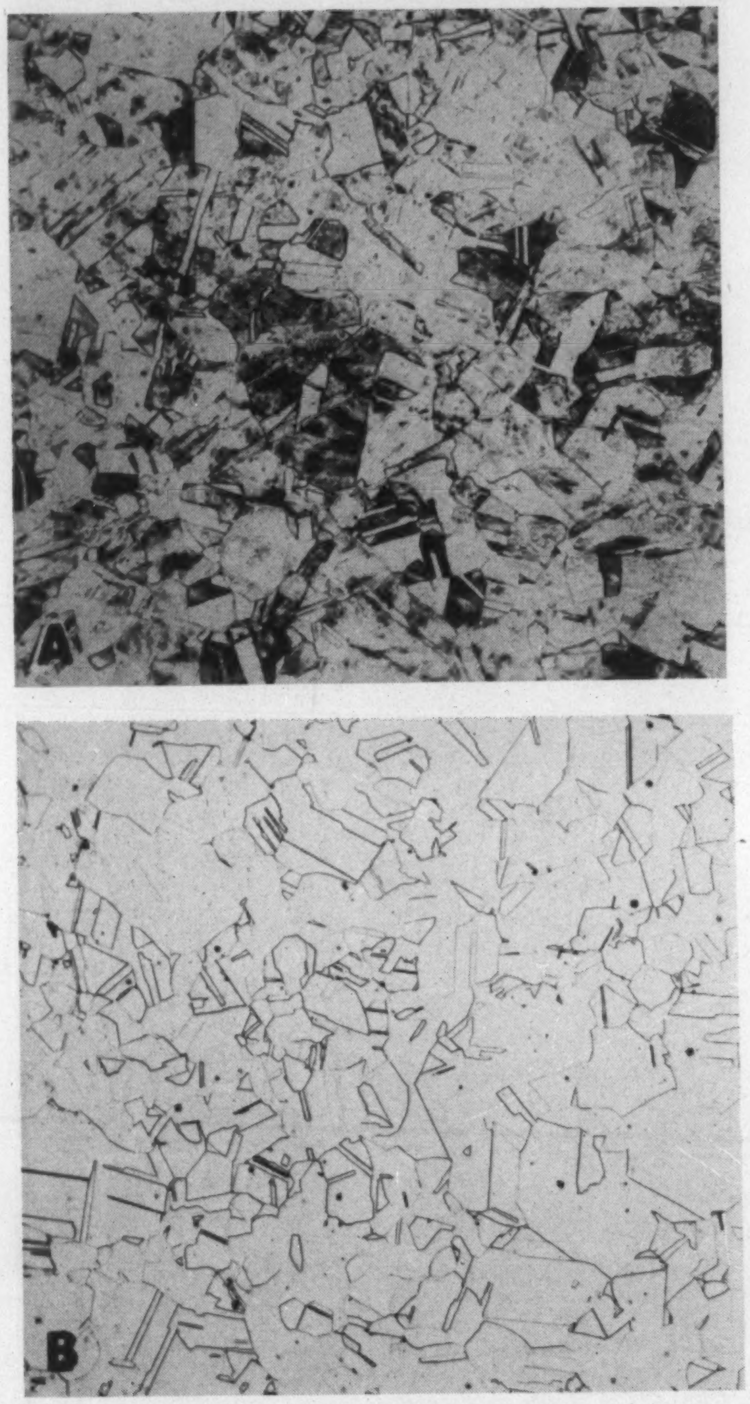


Fig. 5. General view of a low carbon 18 and 8 stainless steel: (A) polished mechanically and showing disturbed metal, (B) polished electrolytically several times in order to remove all disturbed metal. Shows true structure of alloy. Etched with aqua regia in glycerine. 100X.

and 27 per cent Cr, and on austenitic alloys of the 18 per cent Cr, 8 per cent Ni type, with and without the addition of columbium or titanium, and in all cases it was found to yield a result which can be duplicated by mechanical polishing only after the most painstaking and prolonged effort. For this type of alloy the electrolytic method is unquestionably by far the best technique available at present.

Permanent installation of equipment for electro-polishing is unhesitatingly recommended to any laboratory which carries on much metallographic work on these stainless alloys. Good equipment for mechanical polishing is, however, also essential, for in none of the electro-polished specimens examined in the unetched condition were the non-metallic inclusions retained as well as is frequently possible by mechanical polishing. They seem to stand up in relief which not only exaggerates their size but prevents their identification. It must be said, however, that while in the mechanically polished specimens prior to etching, the inclusions are well preserved, after etching the specimens are likely to be badly pitted, owing to the necessity of etching repeatedly in a strongly corrosive solution in order to remove the inevitable disturbed metal. For these reasons, all inclusion work on stainless steel should be carried out on unetched, mechanically well-polished surfaces.

In electro-polishing stainless alloys it is frequently possible to eradicate all grinding scratches long before the last trace of disturbed metal is removed; for instance, a specimen required approximately 1 hr. in the electrolyte before a photomicrograph at 100 dia. could be made without having to include in the field some disturbed metal. The ability to recognize disturbed metal in its various forms is indispensable to those working with low carbon austenitic alloys, for it is practically impossible to prepare mechanically a metallographic specimen of 18 and 8 without distorting the surface metal. These alloys are essentially a homogeneous solid solution, and as such, if not deliberately cold worked, their structure should consist of a structureless ground mass, grain boundaries and, under certain conditions, some carbide particles.

Unfortunately, the structure seen under the microscope generally appears to be far more complex than this; the inevitable distortion of the surface metal produced during polishing gives rise to false structures which greatly complicate the grain pattern. It may be said that if the metallurgist is aware of these possible false structures he is not likely to be confused; but this is often not the case, for the significant structural changes, such as carbide precipitation and the formation of high temperature ferrite, which may occur in these alloys as a result of certain heat treatments and additions of other alloying elements, are so small and of such character as to be either masked by the distortion of the surface metal or confused with the false structures resulting from it. Some of these false structures are illustrated in Figs. 5A, 6A, 6B and 6C.

The general appearance of a polished surface in which disturbed metal is present, and the appearance of the same surface after its elimination are shown at low magnification in Figs. 5A and 5B, respectively. One of the most common manifestations of disturbed metal, illustrated in Fig. 6A, consists of irregularly shaped markings distributed unevenly throughout the grains. Another common form is the straight line markings resembling slip

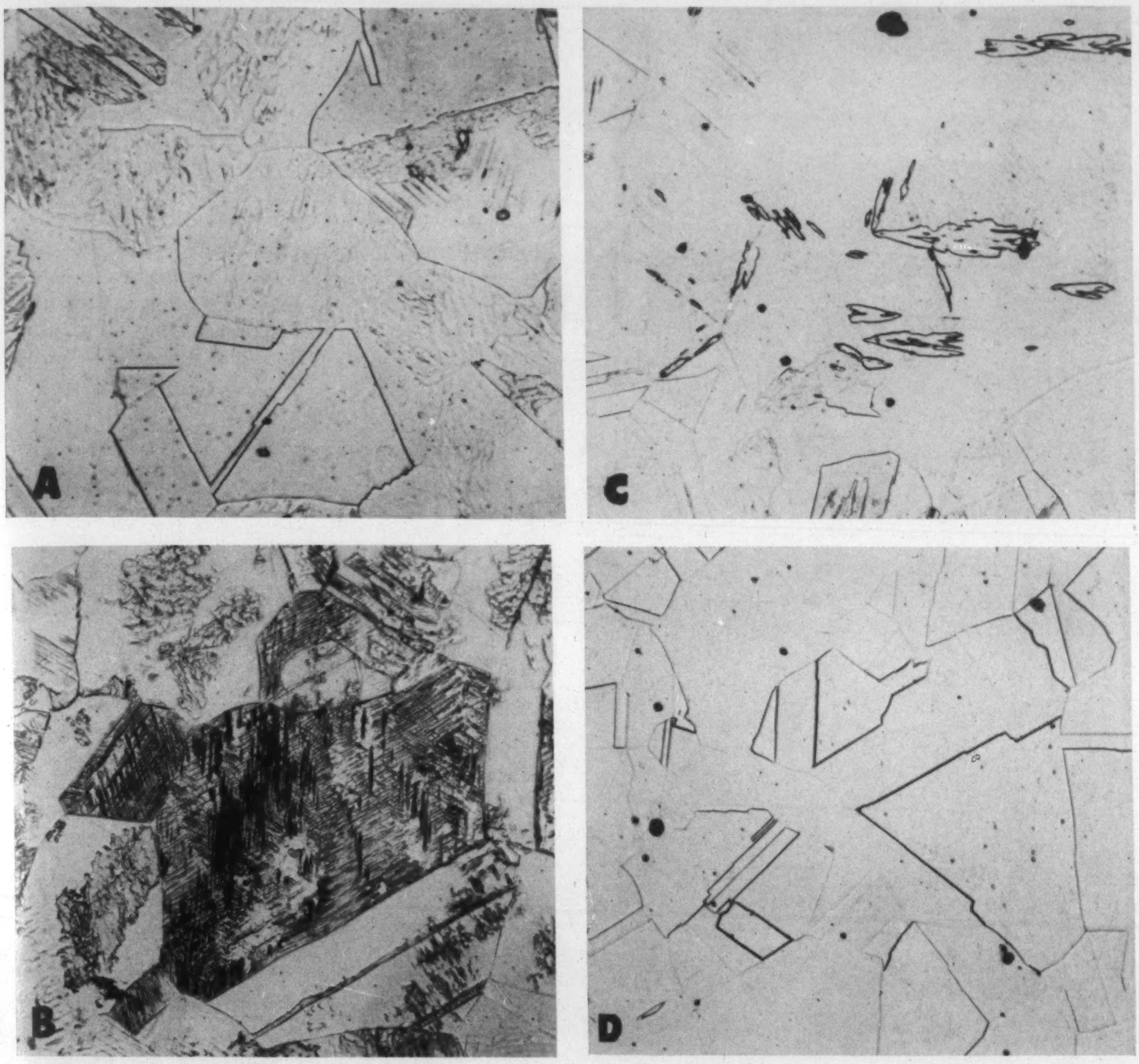


Fig. 6. A low carbon 18 and 8 stainless steel showing false structures resulting from distortion of surface metal during polishing: (A) roughening of the ground mass; (B) straight line marking resembling slip lines: (C) "arrow heads"; (D) same specimen as (A), (B) and (C) after removal of disturbed metal, showing true structure of alloy. All etched with aqua regia in glycerine. 500X.

lines illustrated in Fig. 6B. Less common, but frequently more confusing to those not acquainted with all the false structures resulting from distortion of the surface metal, are the markings sometimes called "arrowheads," illustrated in Fig 6C. These are, of all the false structures, the most difficult to eliminate by the usual mechanical procedure of alternately re-polishing and re-etching. Fig. 6D represents the true structure of the same specimen in which the preceding false structures were noted. Figs. 7A and 7B illustrate respectively the structures of titanium- and columbium-bearing 18 and 8 after complete elimination of the distorted surface metal; of all the austenitic stainless alloys these are among the most difficult to prepare correctly. Note in Figs. 7A and 7B that the carbide particles rich in titanium or columbium tend to occur dispersed more or less at random within the grains; this desirable distribution is not often found in the straight 18 and 8 type, where the chromium-rich carbides generally occur at the austenite grain boundaries.

A number of stainless alloys whose structure consists of austenite and ferrite, such as 18 Cr, 8 Ni, and 2.5 per cent Mo, and those in which the nickel has been replaced by manganese, have also been polished satisfactorily using the procedure recommended for the ordinary 18 Cr-8 per cent Ni alloys.

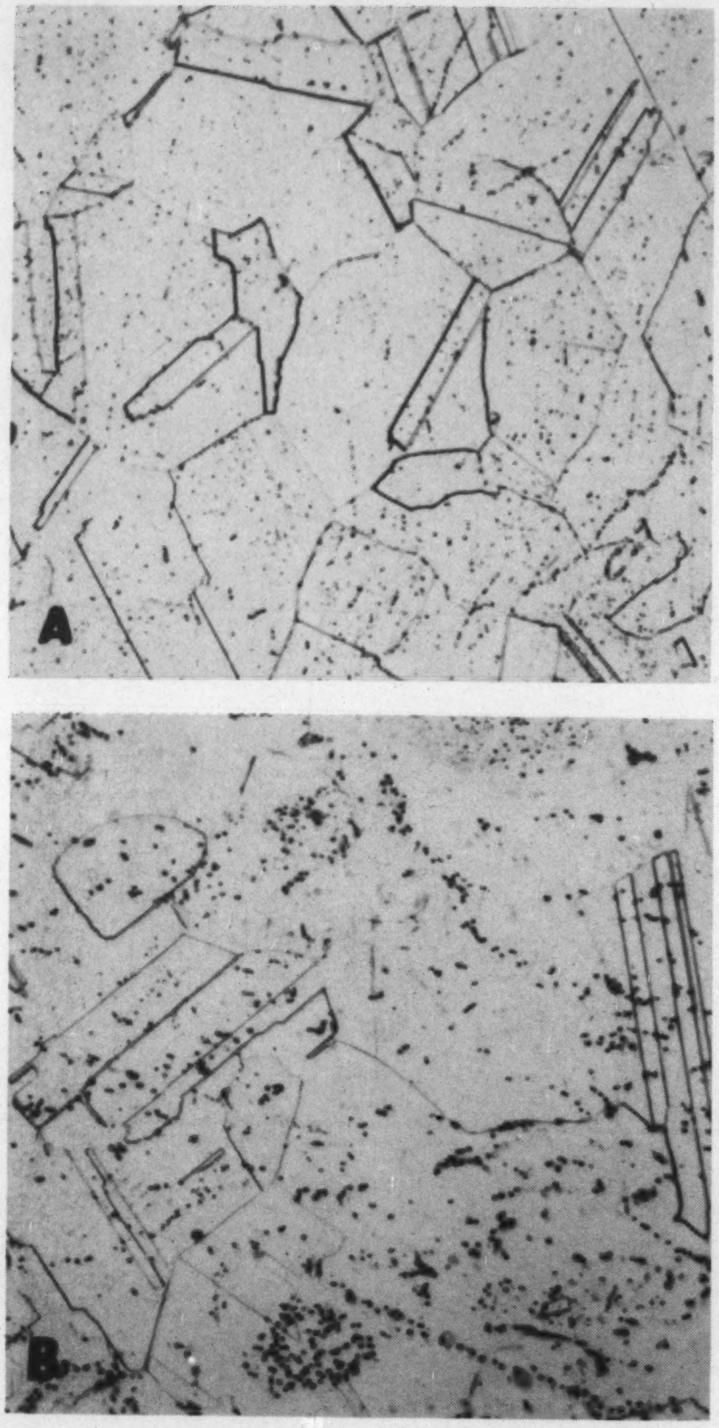


Fig. 7. (A) Titanium treated steel, 0.04 C, 18 Cr, 11 Ni, 0.56 per cent Ti. (B) Columbium treated steel, 0.06 C, 19 Cr, 10 Ni, 0.76 per cent Cb. Both polished electrolytically and etched with aqua regia in glycerine. Note that in these alloys the carbide particles are largely dispersed within the grains, whereas in the straight 18-8 type they are generally found at the austenite grain boundaries. 1000X.

Because of the difficulty of revealing the undistorted structure of these alloys, there has been a trend in recent years to use etching reagents whose action is limited to disclosing the presence of carbides. These reagents may be adequate for special purposes, such as indicating in a general way the presence of carbide precipitation at grain boundaries, but they are inadequate for general use because they not only fail to reveal such significant detail as may often be found within the grains, but they also give an exaggerated picture of the effect of carbide precipitation at the grain boundaries. They frequently show a broadened, deeply etched grain boundary in which the presence of carbide precipitation may be inferred, but in which it is not always possible to actually see the discrete carbide particles. But now that there is a satisfactory method of eliminating disturbed metal, no valid reason exists for not etching these alloys with a reagent, such as aqua regia in glycerine, which attacks all parts of the metal evenly and is capable of revealing all significant details within the grains and at the grain boundaries.

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[3] M. E. Merchant, *Metal Progress*, May 1940, p. 559

Appendix

Warning! Perchloric Reagents May Explode

"Cincinnati, Ohio.—In the article 'Electrolytic Preparation of Iron and Steel Microspecimens" (*Metal Progress* for January, 1940) no explicit mention is made of the possible explosion hazards involved in the use of electrolytic polishing solutions prepared with perchloric acid and acetic anhydride or acetic acid. In fact, this neglect seems to be quite general in much of the literature concerning these methods and their electrolytes.

"Mixtures of perchloric acid with any organic material are well known as potential explosives, especially when heated, and the explosions are usually extremely violent. There is no general agreement as to the conditions for such explosions and their causes. The behavior seems to be rather erratic and unpredictable. Furthermore, hot perchloric acid forms a very explosive product with bismuth or bismuth alloys.

"These facts are obviously pertinent to the use of the above-mentioned polishing electrolytes, and indicate that protective measures should be taken when such solutions are employed, *particularly at the time of mixing.* Jacquet and Rocquet's injunction in *Comptes Rendus*, p. 102 (1919) to chill the ingredients before mixing should receive emphasis, for a large amount of heat is evolved when compounding mixtures of perchloric acid and acetic anhydride. The danger of using specimens mounted in organic substances such as bakelite or lucite (as mentioned in the above-noted article in *Metal Progress*), or of allowing the electrolyte to come into contact with any organic material cannot be too strongly emphasized.

"In addition we wish to point out the danger of attempting to use electrolytes containing perchloric acid to polish bismuth or bismuth alloys. In a rapid search through the literature on electrolytic polishing we have noticed no reference to this last mentioned hazard.

"The purpose of this letter is not so much to discourage the use of electrolytes containing perchloric acid, but to prevent gravely serious accidents that may occur through ignorance of the dangers which accompany careless handling of the solutions."—M. E. Merchant, Basic Science Research Laboratory, University of Cincinnati, *Metal Progress*, Vol. 37, May 1940, p. 559.

CONCLUDED FROM MARCH

Practical Metallography of the Stainless Steels–IV

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The metastability of the austenitic stainless steels is evidenced by their reaction to cold deformation. As pointed out already, it is impossible to harden these alloys by heat treatment, but only a moderate amount of cold working serves to greatly increase their hardness and tensile strength. The effect of cold working is to facilitate the formation of a stable ferritic phase through the breakdown of austenite. Since ferrite holds less carbide in solution than does austenite, it is expected that some carbides may be precipitated in connection with the formation of ferrite. Such is the case as shown by Fig. 48, which illustrates the typical structure of cold worked 18 and 8 stainless steel which consists of distorted polyhedral austenite grains with many markings resembling slip bands. In the cold worked condition the austenitic stainless steels are slightly magnetic, the degree depending upon analysis balance between chromium and nickel and the amount of cold deformation.

The degree to which the austenitic stainless steels will respond to cold working depends to a large extent upon the analysis balance, especially the chromium-nickel ratio. In general, alloys with a high proportion of chromium are more susceptible to work hardening than ones with chromium low in proportion to nickel. This is shown graphically by Fig. 51. Reheating cold worked material to above 1850 deg. F. serves to revert it into the austenitic state by redissolving ferrite and carbides. In addition, this operation serves to effect some grain refinement.

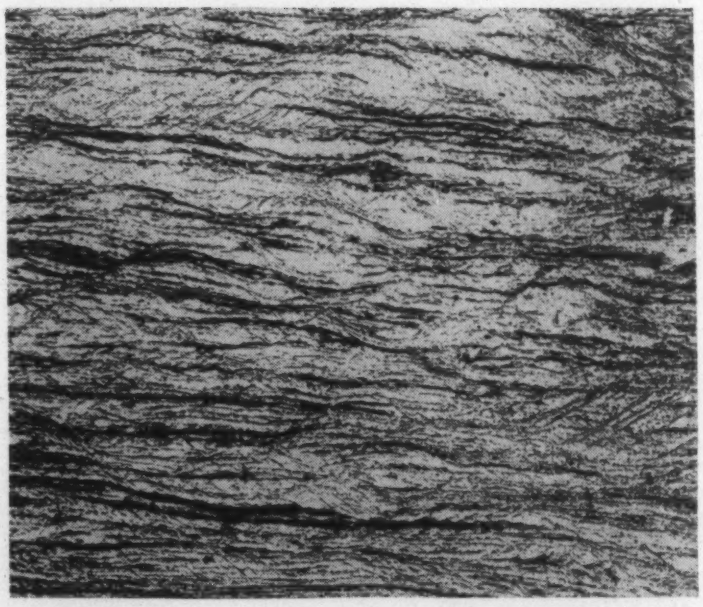

Fig. 48. Structure of severely cold worked 18 and 8 stainless steel. Alloy is quite magnetic in this condition. Hardness Rockwell "C" 40. Etchant: Aqua regia. Mag. 200X.

When the austenitic stainless steels are heated for prolonged periods in the range of 900 to 1650 deg. F. carbides, rich in chromium, are precipitated as particles, usually along the grain boundaries, (Fig. 52) in annealed material, and also in the region of slip planes in cold worked metal. In addition, the alloy becomes slightly magnetic indicating that some ferrite has been formed in conjunction with precipitation of carbides. This phenomenon is a process of precipitation from solid solution, analogous in many ways to "precipitation hardening," a characteristic of such alloys as duralumin. However, in precipitation hardening the precipitated constituent is uniformly distributed throughout the grains and the metal undergoes no phase change. On the other hand, in the austenitic stainless steels, the precipitation of carbides is preferential and they are concentrated along the grain boundaries. Since austenite will retain about 0.02 per cent C in solution, any amount in excess of this will be retained in a

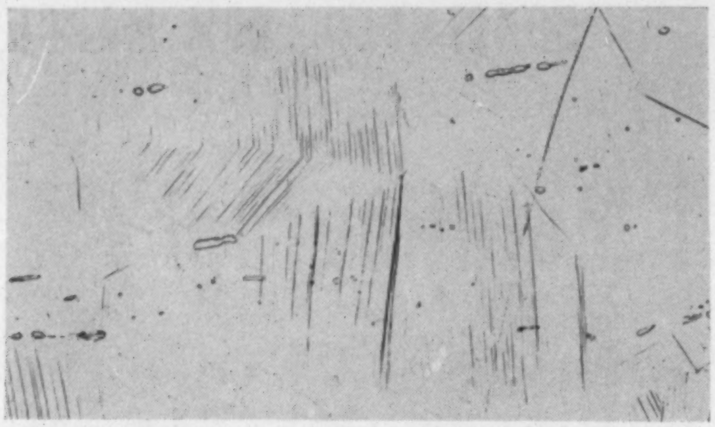

Fig. 49. Structure of slightly cold worked 18 and 8 stainless steel. Alloy is only faintly magnetic. Hardness Rockwell "B" 90. Etchant: Aqua regia. Mag. 200X.

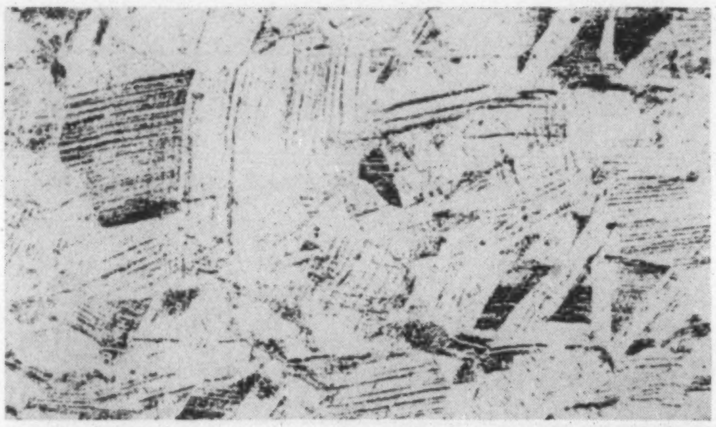

Fig. 50. Structure of cold worked 18 and 8 stainless steel treated at 1300 deg. F. Note that most of the precipitated carbides are along slip planes instead of the grain boundaries. Hardness 255 Brinell. Etchant: Sodium cyanide, electrolytic. Mag. 200X.

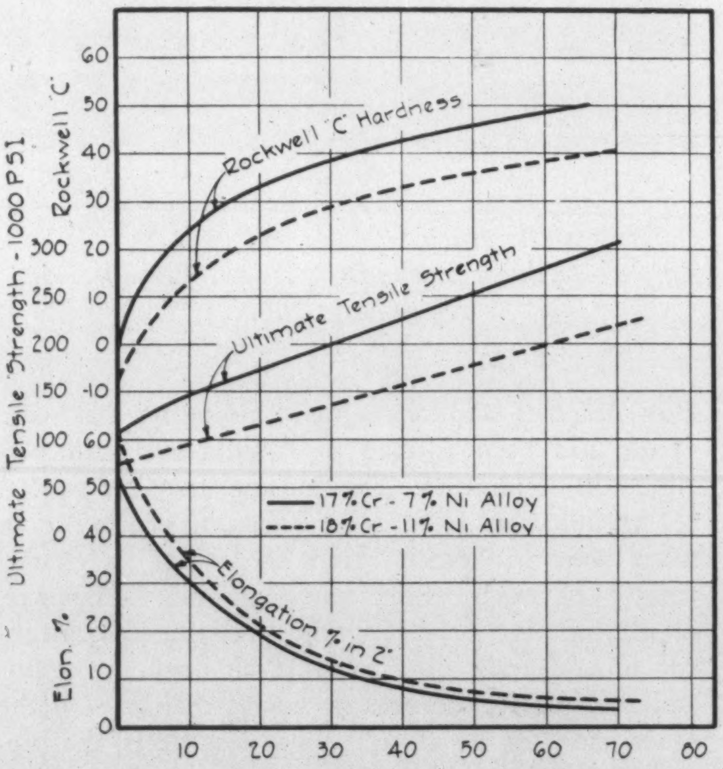

Fig. 51. Illustrating the difference in work-hardening characteristics between low and high alloy content 18 and 8 stainless steel wire.

supersaturated state on quenching from above 1850 deg. F. and a large proportion will, subsequently, precipitate out as chromium carbides when reheated within the range of 900 to 1650 deg. F. In the case of the 18 and 8 stainless steels, as shown by Fig. 13, increasing the carbon content serves to widen the temperature range where carbide precipitation will occur on reheating in the "sensitizing" zone.

Carbide Precipitation

All the austenitic stainless steels are susceptible to carbide precipitation, some more than others, and the extent to which it occurs depends largely on carbon content. The practical significance of this phenomenon is that the acid corrosion resistance of these stainless steels is materially reduced when precipitated carbides are present along the grain boundaries. Under conditions of severe acid corrosion, "sensitized" material, i.e., material which has been heated in the carbide precipitation zone, attack occurs along the grain boundaries leaving the grains themselves only moderately attacked. Chemical analysis of the carbides precipitated in 18 and 8 stainless steel, as recently reported, showed that they contained as much as 90 per cent Cr and carbon 20 to 30 times greater than in the alloy itself. This serves to account for the low resistance of the grain boundary areas to acid attack, as it is logical to assume that, during the formation and agglomeration of these carbides, a depletion of the adjoining metal of chromium and carbon occurs which severely reduces its resistance to attack by acids and corrosive gases. Also, the appearance of magnetism in "sensitized" 18 and 8 material is undoubtedly due to localized areas being so depleted in carbon and alloying element that the phase change from austenite to chromium-ferrite has occurred.

Carbide precipitation in the austenitic stainless steels occurs very rapidly, only a few minutes at about 1400 deg. F. being sufficient to thoroughly "sensitize" 18 and 8 material. However, as this change is a function of time and temperature, sensitization occurs at temperatures as low as 900 deg. F., but it will proceed more slowly. On the other hand, if the alloy is heated for several hours within the sensitizing zone, it will become more stable and less susceptible to intergranular attack. This is brought about through the effect of prolonged heating which permits migration of alloying elements into the depleted zones and thus restores to normal their corrosion resistance. The effect of such a treatment on the acid resistance of 0.05 per cent C, an 18 and 8 alloy, is shown by Fig. 55.

Several acid corrosion methods are in use for determining the susceptibility of the austenitic stainless steels to intergranular corrosion, but the one generally used is the Strauss test. In this test the material is first heated within the sensitizing zone and then subjected to a boiling solution of 10 per cent sulphuric acid and 10 per cent copper sulphate in a reflux condenser for 24 hrs. If intergranular attack occurs, slight bending will cause a roughening of surface and in severe cases the metal will completely disintegrate. In contrast to normal metal, which gives off a metallic ring when struck with a bar, metal severely corroded intergranularly will not ring when struck, but sound "dead."

In addition, the Huey Nitric Acid test is used for determining extent of carbide precipitation in the 18 and 8 stainless steels. This test consists in subjecting the material to a boiling solution of 65 per cent nitric acid for two or more 24-hr. periods. Samples are weighed before and after test and loss in weight determined, which for comparison purposes is converted to inches penetration per month. It has been found that if the rate is less than 0.004 in./pen. per mo. the material is not susceptible to intergranular attack as revealed by the Strauss test.

Carbon and Intergranular Corrosion

From the above discussion it will be seen that carbon is the contributing cause of intergranular corrosion and the obvious remedy would be to reduce the carbon content in the austenitic stainless steels to such a low limit that no carbide would be precipitated. To accomplish this would necessitate the production of material with carbon under about 0.02 per cent which is extremely difficult as well as expensive. However, 18 and 8 stainless steel is being regularly produced with carbon content of 0.04 to 0.06 per cent and, although such material is not entirely immune to carbide precipitation, fewer carbides are precipitated, resulting in a greater resistance to intergranular attack than higher carbon content material. Also, increasing the alloy content somewhat above the 18 and 8 range further increases the resistance of these alloys to intergranular corrosion.

Intergranular corrosion is no longer the industrial problem it once was, owing to a better understanding among users of the nature of this phenomenon and how to avoid or correct the condition when once present. Also, in recent years several 18 and 8 stainless steels have become available which, for all practical purposes, are not susceptible to intergranular attack when heated within the sensitizing zone. Such alloys contain titanium or columbium, which combine with the excess carbon present to form highly stable carbides. In practice, titanium to the amount of six times the carbon content is added, and in the case of columbium, 10 times carbon content. If these alloys are treated in the range of 1550 to 1650 deg. F., all the excess carbon is precipitated in the form of titanium or columbium carbides and such material is termed "stabilized," as the metal is sta-

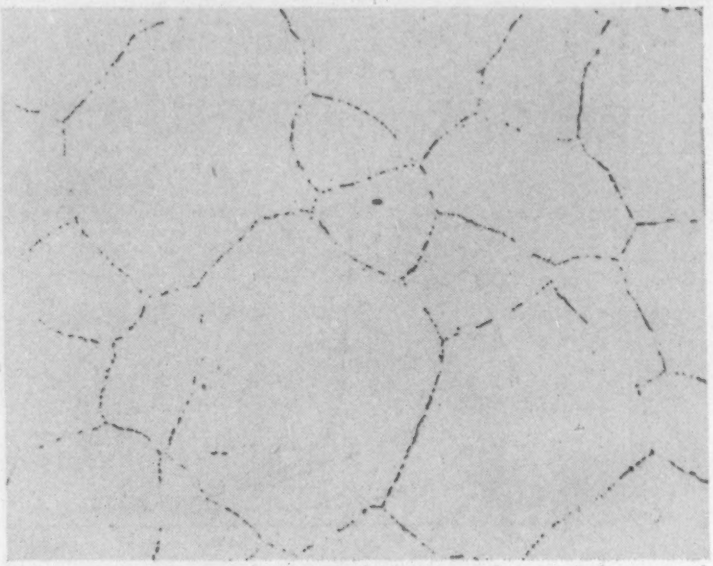

Fig. 52. Structure of annealed 18 and 8 stainless steel treated in the "sensitizing" zone. Carbides are precipitated along grain boundaries. Etchant: Sodium cyanide, electrolytic. Mag. 200X.

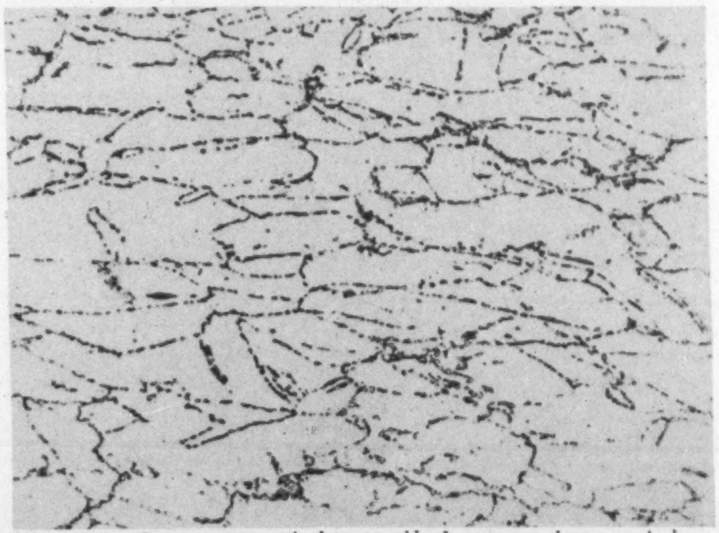

Fig. 53. Structure of hot rolled 18 and 8 stainless steel bar. Rate of cooling was not sufficient to maintain carbides in solid solution. Etchant: Sodium cyanide, electrolytic. Mag. 200X.

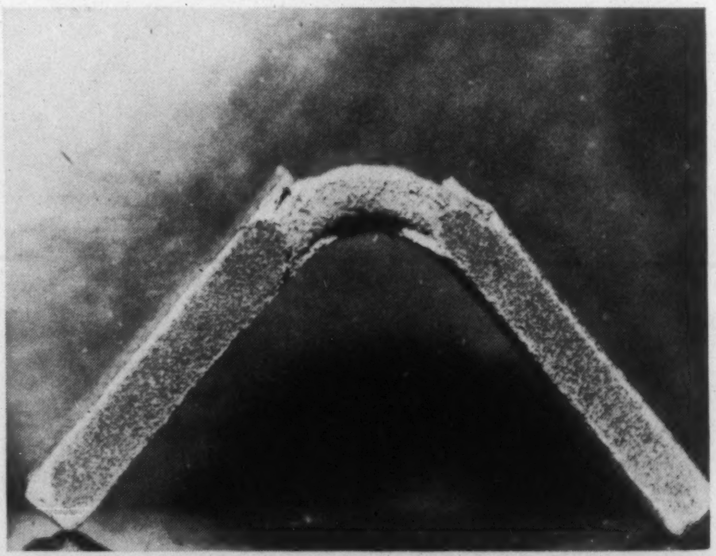

Fig. 54. Showing disintegration of sensitized 0.08 per cent C, 18 and 8 stainless steel after exposure to the Strauss test. One-half actual size.

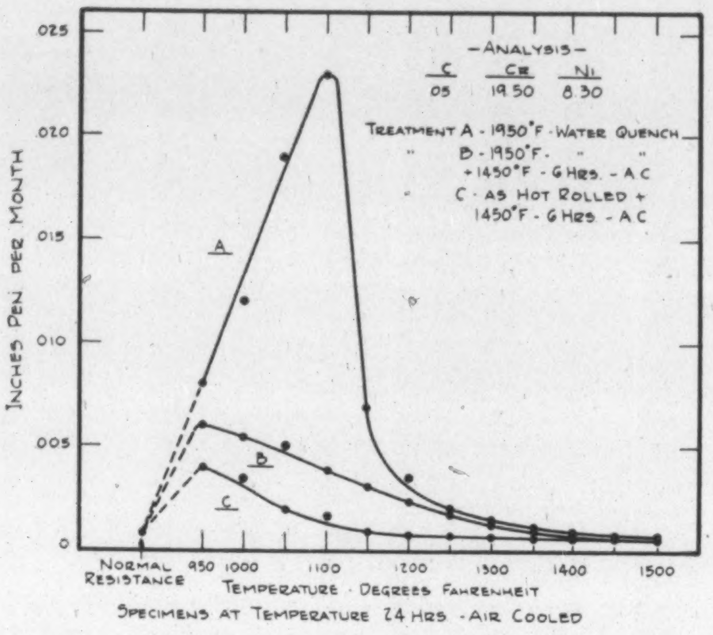

Fig. 55. Heating for extended periods in the "sensitizing" zone serves to restore normal resistance to this alloy against attack by 65 per cent boiling nitric acid. Rates shown represent attack during second 48-hr. period.

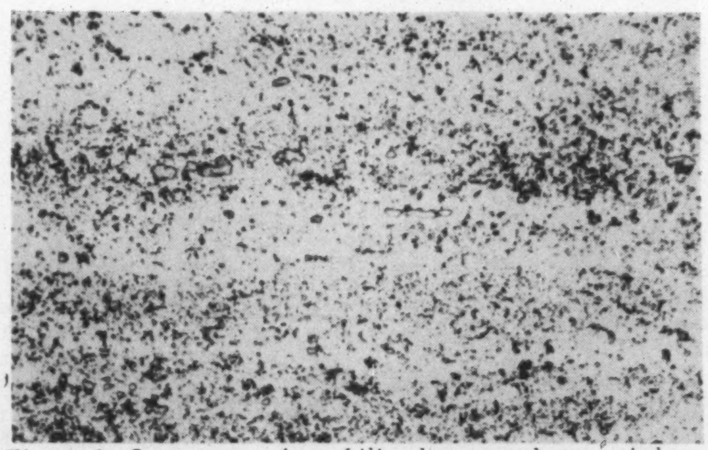

Fig. 56. Structure of stabilized 18 and 8 stainless steel containing 0.73 per cent Cb, annealed and stabilized by heating at 1600 deg. F. for 6 hrs. Note that carbide particles are dispersed throughout matrix rather than along grain boundaries. Etchant: Chromic acid, electrolytic. Mag. 500X.

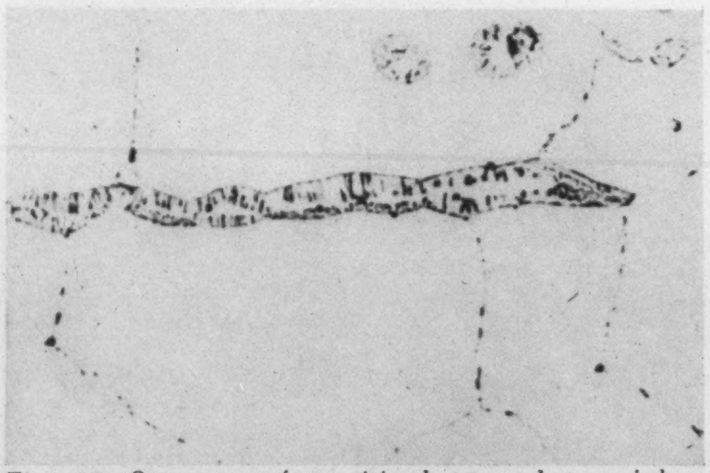

Fig. 57. Structure of sensitized 18 and 8 stainless steel containing delta ferrite. Note that a large proportion of carbides are precipitated in delta ferrite pools. Etchant: Sodium cyanide, electrolytic. 500X.

bilized against further changes when exposed to lower temperatures. It is considered necessary to give the 18 and 8 titanium material a stabilizing treatment in order to obtain full effect of titanium but in the case of columbium, this is not so.

Typical microstructure of 18 and 8 columbium material after stabilizing is shown by Fig. 56. It will be noted that the carbide particles are dispersed uniformly throughout the matrix, rather than predominantly along the grain boundaries as would be the case of 18 and 8 without this stabilizing element. Titanium oxidizes more readily than columbium and hence, it is difficult to transfer a sufficient amount from an 18 and 8 welding rod to the deposited metal to stabilize the carbides present. On the other hand, columbium is not so easily oxidized and sufficient amounts can be transferred to the deposited metal from columbium 18 and 8 welding rods to effect stabilizing of carbides. In view of this, there is no advantage in using the 18 and 8 titanium alloy for welding rods.

As pointed out in a previous paragraph, lowering the carbon and increasing the chromium content of the austenitic stainless steels favors the formation and preservation of high temperature chromium-ferrite (delta iron). The microstructure of such an alloy is shown by Fig. 45. When a fairly large amount of chromium-ferrite is preserved, the alloy is appreciably magnetic. The addition of molybdenum and silicon also promote the formation of high temperature chromium-ferrite. When such alloys are heated within the sensitizing range, it is found that the carbides tend to form predominantly in the chromium-ferrite areas, which being disconnected, do not promote intergranular corrosion (Fig. 57). However, unless these alloys are quite low in carbon, some intergranular corrosion may occur when subjected to severe acid attack.

When the proportion of chromium to nickel is high, such as in an alloy containing 29 per cent Cr and 9 per cent Ni, the normally annealed structure consists of austenite pools imbedded in a chromium-ferrite matrix as shown by Fig. 58. In this condition the alloy is quite ductile and strongly magnetic. However, when such an alloy is heated for long periods in the temperature range of 1100 to 1650 deg. F., a portion of the ferrite is converted into the compound FeCr (sigma phase) and austenite. The structure of a 29-9 alloy, after heating in this range, is shown by Fig. 59. The ferritic constituent has been largely converted into the sigma phase and austenite, resulting in the alloy becoming non-magnetic, exceedingly brittle and quite hard. It is reported that sigma phase, in addition to occurring in certain of the chromium-nickel stainless steels, can also exist in the straight chromium stainless steels with chromium above about 20 per cent. This, no doubt, is the reason for such alloys becoming brittle when heated within the above range and slowly cooled. In all cases, sigma phase may be redissolved by heating above about 1850 deg. F., and subsequent rapid cooling restores normal ductility and structure.

Acknowledgments

The author wishes to express his appreciation for the assistance given by L. F. Weitzenkorn who made many of the photomicrographs used. To the management of the Rustless Iron and Steel Corp., thanks are due for their permission to publish this work.

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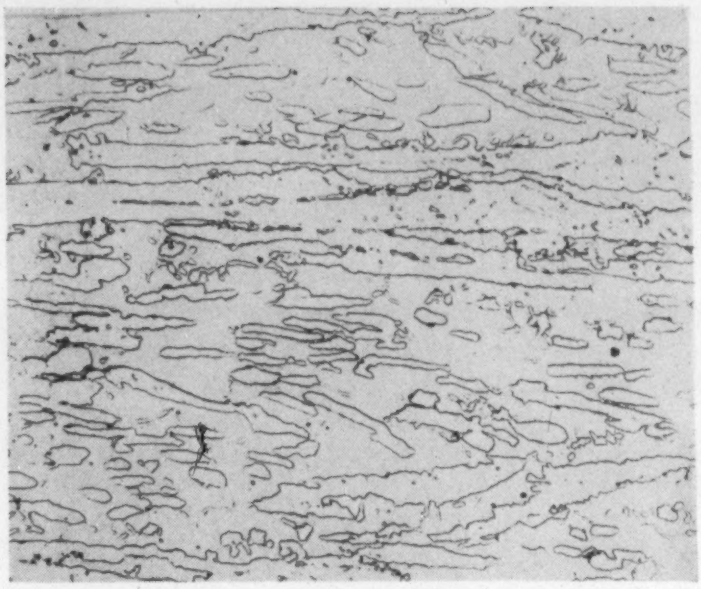


Fig. 58. Annealed structure of 0.12 per cent C, 29 per cent Cr, 9 per cent Ni alloy. Austenitic pools in ferritic matrix. Material is ductile and magnetic. Hardness 229 Brinell. Etchant: Aqua regia. Mag. 200X.

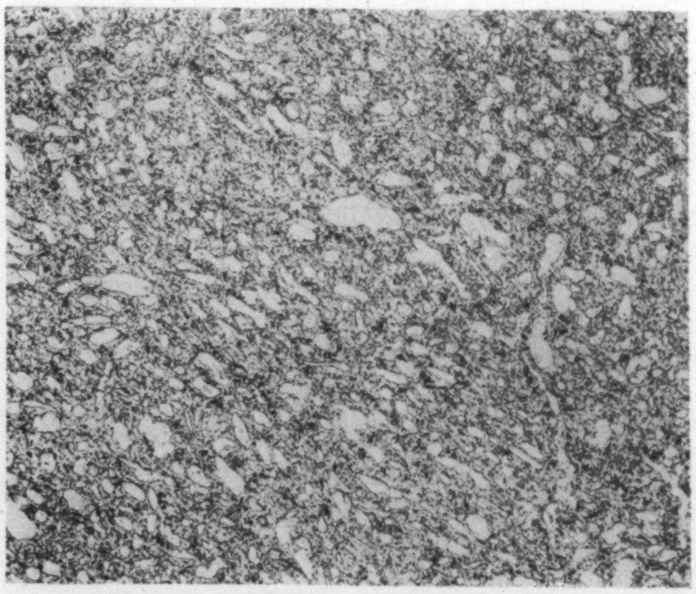


Fig. 59. Structure of 0.12 per cent C, 29 per cent Cr, 9 per cent Ni alloy, consisting of austenitic pools in matrix of austenite and sigma phase, after slow cooling from above 1400 deg. F. Material is exceedingly brittle and non-magnetic. Hardness 415 Brinell. Etchant: Aqua regia. Mag. 200X.

Metallography of Tin

The authors describe procedures relating to the metallography of block tin and hot-dipped tin plate which have proven satisfactory. Representative photomicrographs are shown; among them is one showing a cross section of tin plate of commercial coke-grade revealing the iron-tin alloy layer. Others show the total thickness of the coating on specimens which had been heated for 1- and 2-hr. periods at 400, 425, 475 and 500 deg. F. The authors believe that photomicrographs of cross sections of such light tin coatings have not been shown previously in the literature.—The Editors.

DURING RECENT YEARS, particular attention has been devoted to the various types of metallic coatings used for the protection of steel from corrosion. In many instances the coating metal is appreciably softer than the base to which it is applied. Among the common elements, tin is in many respects an ideal coating metal for steel, and for many years has found extensive application in the manufacture of food containers. That hot-dipped tin plate coatings are composed of an iron-tin alloy layer in addition to an outer layer of tin is well known but the metallography of these coatings has been extremely difficult. The indifferent results obtained heretofore can be attributed largely to rounding or beveling of the coating during polishing and the lack of a satisfactory etchant. The preparation of an optically flat cross section of such a product often requires the development of unusual methods in order to produce the clarity, detail, and flatness essential to the preparation of good photomicrographs.

The present paper describes in detail metallographic procedures for the preparation of block tin specimens and cross sections of commercial hot-dipped tin plate coatings. The development of a suitable technique for block tin was necessary as a result of experimental work conducted to obtain recrystallization data on cold worked tin. It was anticipated that these data would be of aid in the more difficult problem of preparing cross sections of tin plate.

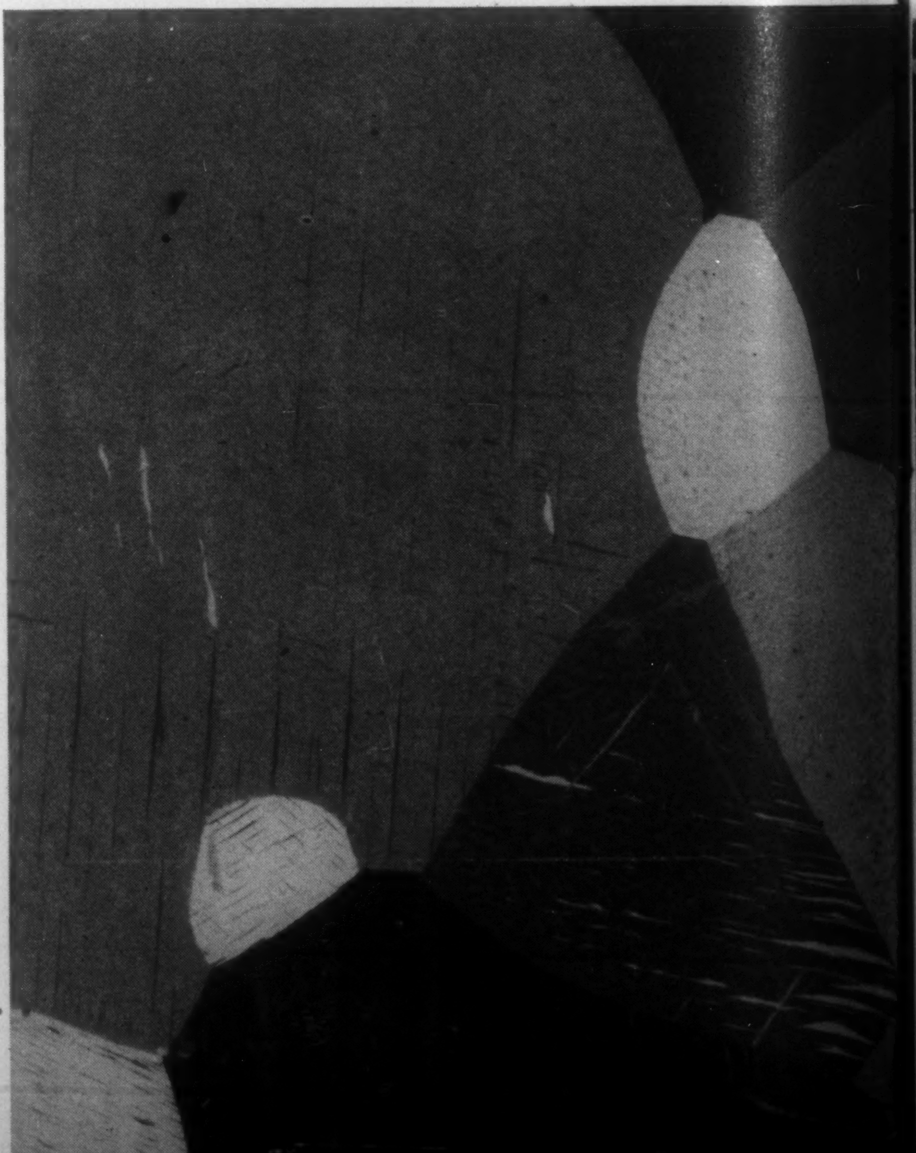
Metallography of Block Tin

P. A. Jacquet[1] describes a method of polishing block tin electrolytically and shows some very beautiful photomicrographs prepared by this method. The procedure requires a flat plane surface for suitable treatment. When there is danger that undue cold work may result from preparation of the samples, this method is eminently satisfactory. Since, however, the apparatus for electrolytic treatment may not always be available it is believed that, with care, the method of preparation of block tin described below can be used satisfactorily without danger of recrystallization of the tin in the final polishing operation.

Outline of Procedure in the Metallographic Preparation of Block Tin:

1. Specimen filed flat.
2. Hand ground on 0, 2/0 and 3/0 emery or carborundum metallographic papers.
3. Polishing operation:
   (a) 3 F alundum in water on horizontal lap covered with billiard table felt. Lap speed 300 r.p.m.
   (b) 500 alundum—same procedure as (a).
   (c) Jewelers rouge in water on horizontal lap covered with high grade silk velvet. Lap speed 50 to 75 r.p.m.
4. Etching agent—alcoholic acid ferric chloride, as described by Taffs[2]:

Fig. 1. Chempur block tin—cold reduced 50 per cent by compression and annealed 3 hrs. at 350 deg. F. Etchant: Alcoholic acid ferric chloride. 20X.



and Tin Coatings on Steel

by O. E. ROMIG and D. H. ROWLAND

Asst. Research Engr. and Senior Metallurgist, respectively, Research Laboratory, Carnegie-Illinois Steel Corp.,

Ferric chloride	2 g
Water	30 ml
Hydrochloric acid	5 ml
Ethyl alcohol (190 proof)	60 ml

5. Alternate polishing and etching necessary in (a), (b), and (c).

A specimen of convenient size having been obtained by sawing or casting, a flat surface may be secured by filing. A 12- or 16-in. mill file is satisfactory for this purpose. The best procedure is to push the specimen against the cutting edge of the file, preferably in one direction only. Back-and-forth rubbing tends to round the specimen and introduce chatter marks. After filing, hand grinding is accomplished on the various grades of metallographic papers noted. Grinding on each grade of paper is continued until scratches from the preceding paper are removed. The specimen should be rotated 90 deg. on changing from one grade of paper to the next.

The polishing laps, or discs, may be of any convenient size, but they should revolve at comparatively slow speeds in order to prevent excessive flowing of the tin surface. Alternate polishing and etching on laps impregnated with 3F and 500 alundum, or their equivalent, removes practically all of the cold worked metal remaining from the coarse grinding operations. In the final polish, using rouge as the abrasive, the specimen is again alternately polished and etched until the remaining cold worked metal has disappeared.

In Fig. 1 is shown the grain size of a sample of Chempur block tin cold reduced 50 per cent by compression and annealed for 3 hrs. at 350 deg. F. An additional polish and etch was necessary to com-

Fig. 2. Same as Fig. 1 after rubbing gently with file and repolishing. Recrystallization prevalent along file marks. Polishing operation required 10 min. Etchant: Alcoholic acid ferric chloride. 20X.

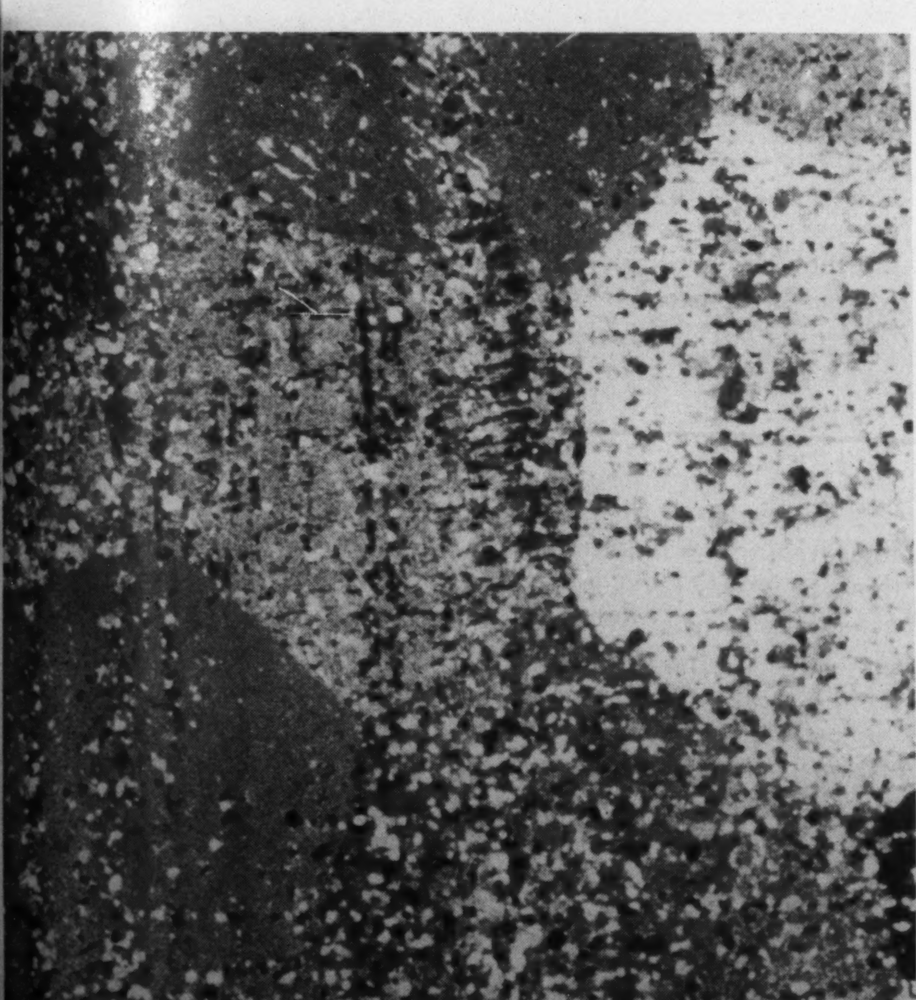
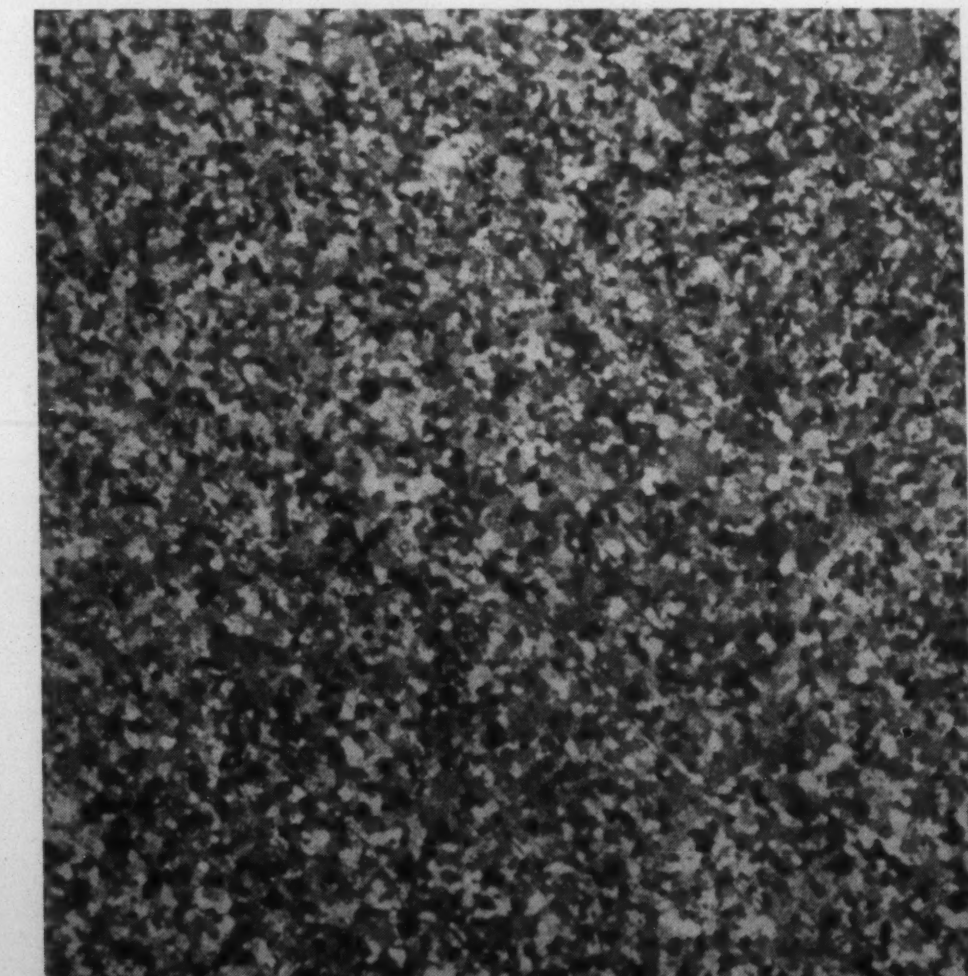


Fig. 3. Same as Fig. 1 after rubbing gently with 3/0 metallographic paper and repolishing. Recrystallization complete on surface of specimen. Polishing operation required 1½ min. Etchant: Alcoholic acid ferric chloride. 35X.



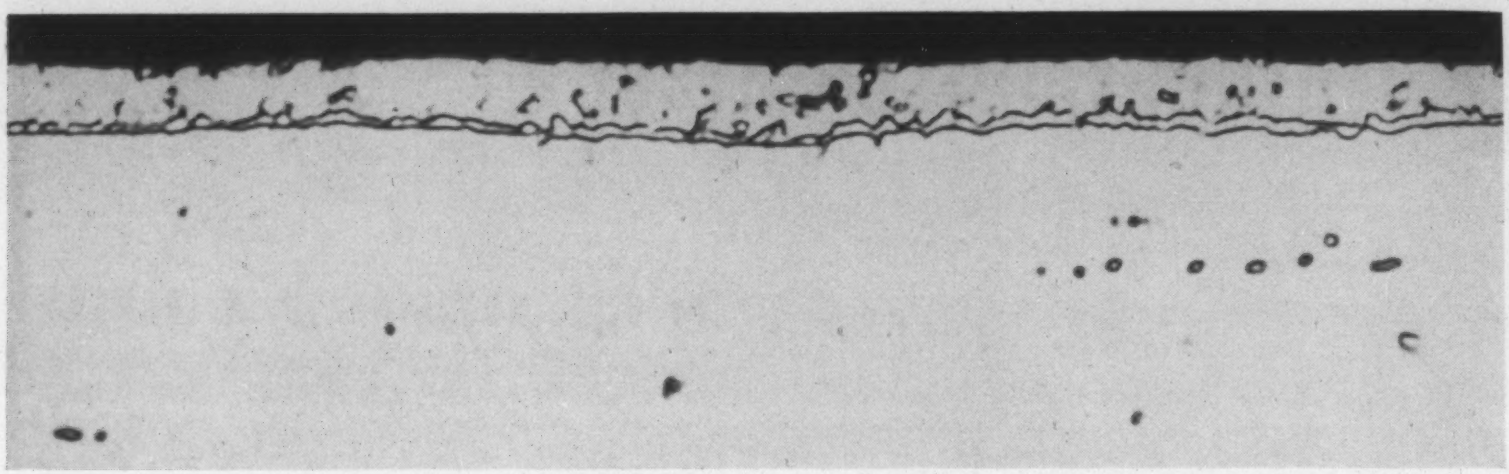


Fig. 4. Cross section of coke tin plate. Average weight of coating,, 1.17 lbs. per base box. Double etched to reveal iron-tin alloy layer. 2500X.

pletely remove the effects of cold work noted in this photomicrograph. The recrystallization occurring at room temperature (70°F.) when the polished and etched surfaces of two such specimens were rubbed gently with a file and on 3/0 metallographic paper, respectively, is shown in Figs. 2 and 3. These results, when supplemented by additional data, indicated that considerable care must be exercised in the preparation of tin for metallographic examination if erroneous conclusions as to grain size were to be avoided.

Metallography of Commercial Hot-Dipped Tin Plate

The study of the variation in thickness of the iron-tin alloy layer formed during the manufacture of hot-dipped tin plate is of interest because of the relation of the coating structure to its forming qualities. Experimental data obtained by Wever and Reinecker,[4] Westgren and Phragmen,[5] Edwards and Preece,[6] Ehret and Westgren,[7] W. E. Hoare,[8] Jones and Hoare,[9] and others, appear to indicate that this layer is composed chiefly of the compound $FeSn_2$ possessing brittle characteristics. It seemed logical, therefore, that the development of a metallographic method for revealing the iron-tin alloy on cross sections of tin plate should be of value in the solution of some of the problems encountered in the tin plate industry.

The value of metallographic examination of tin coatings, when studying adherence and porosity, is aptly shown by J. J. Macnaughtan and J. C. Prytherch.[10] Their paper exhibits some excellent photomicrographs of tin coatings on steel which were prepared by H. J. Taffs.[3] Among these photomicrographs is one showing the iron-tin alloy layer and tin coating on a specimen of charcoal tin plate with weight of coating 5 lbs. per base box. This photomicrograph was of interest because specimens of charcoal plate of American manufacture which have been examined by the present authors did not show rectilinear shaped alloy but rather that typical of coke-grade plate, (Fig. 4).

When it is considered that the average thickness of the coatings on coke-grade tin plate ranges from about 0.00006 to 0.00012 in., and on charcoal-grade plate from about 0.00015 to 0.0005 in., it becomes apparent that, if optically flat surfaces are to be maintained during the polishing of cross sections, some means of supporting the edge of the tin must be employed. This is particularly true if the full width of the coating is to be photographed at magnifications of 1000 dia. or more. Experience has shown that specimens placed surface to surface in mountings do not yield satisfactory results when polished because it is usually impossible to determine the line of demarcation between the two coatings. This circumstance makes the use of separators between specimens desirable when a number of specimens are to be polished simultaneously.

Materials utilized for supporting the edges of the tin coatings in the preliminary stages of this work included: Hard waxes, fusible alloys, metal strips, and acid hardening bakelite. Tin plate specimens cannot be satisfactorily mounted in a bakelite press because the tin coating will flow excessively at press temperatures and pressure, thus giving a false conception as to the original width of the coating. Acid hardening bakelite had the disadvantage that it contracted continuously on standing, and its use did not eliminate the need of liners between specimens. Samples of tin plate electroplated with iron, copper, nickel, and chromium were mounted in various ways but the results obtained on polishing were somewhat discouraging. Thin steel strips, about 0.001 in. thick as inserts between specimens, gave fair results except for seepage of the etching reagents, the etching characteristics of which added further difficulties to an already troublesome problem. Additional work disclosed that a strip of cellophane placed between specimens effectually stopped leakage of the etching reagents in bolted mountings. When a tight fit was obtained, very little rounding of the tin occurred during polishing.

Finally, it was found that if the tin plate specimens were individually dipped in bakelite lacquer, allowed to dry in air for 30 min. and then heated for 20 min. at about 275 deg. F., an excellent mounting could be obtained by bolting the specimens together with a strip of cellophane between each. No leakage troubles were experienced and the thin shell of bakelite (about 0.001 in. thick on each side of a specimen) was of adequate hardness to support satisfactorily the edges of the tin coating. Experimental work by the authors and other investigators[9, 11] has indicated that the growth of the iron-tin alloy is very slow, even at the melting point of tin, therefore heating for the prescribed time at 275 deg. F. introduces no visible change in the width of the alloy layer. Continued use of the method just described has shown that cross sections of tin coatings, whether hot-dipped or electroplated, as thin as 0.000015 in. thick can be successfully prepared for photographing.

A number of etching reagents for tin, the compositions of which were obtained from the literature, were tried in the preliminary stages of the present investigation but all excessively stained and over-etched the tin. Accordingly, attention was given to the development of a reagent possessing more desirable etching characteristics for tin plate coatings. Two such reagents were discovered, each having a special application. One of these, for use on commercial coke-grade plate, consists of a mixture of nitric and hydrofluoric acids in glycerine; the other, a solution of hydrofluoric acid in absolute methyl alcohol, is applied in experimental work where the alloy layer and tin are often much thicker than on commercial plate. When properly employed, neither of these reagents stain the tin and they attack it sufficiently to define the iron-tin alloy layer boundary adjacent to the tin. A subsequent etch with picral, which attacks only the steel base, defines the boundary adjacent to the steel. It can be seen, therefore, that the application of a double etch is apparently necessary to outline both sides of the alloy layer.

The following method for mounting, polishing, and etching hot-dipped tin plate samples may, at first glance, appear to be long and tedious, but practice in its use will yield results which have in the past defied accomplishment:

Outline of Procedure in the Metallographic Preparation of Cross Sections of Hot-Dipped Tin Plate.

1. Dip, dry, and bake tin plate specimens in bakelite lacquer according to direction supplied with the lacquer.

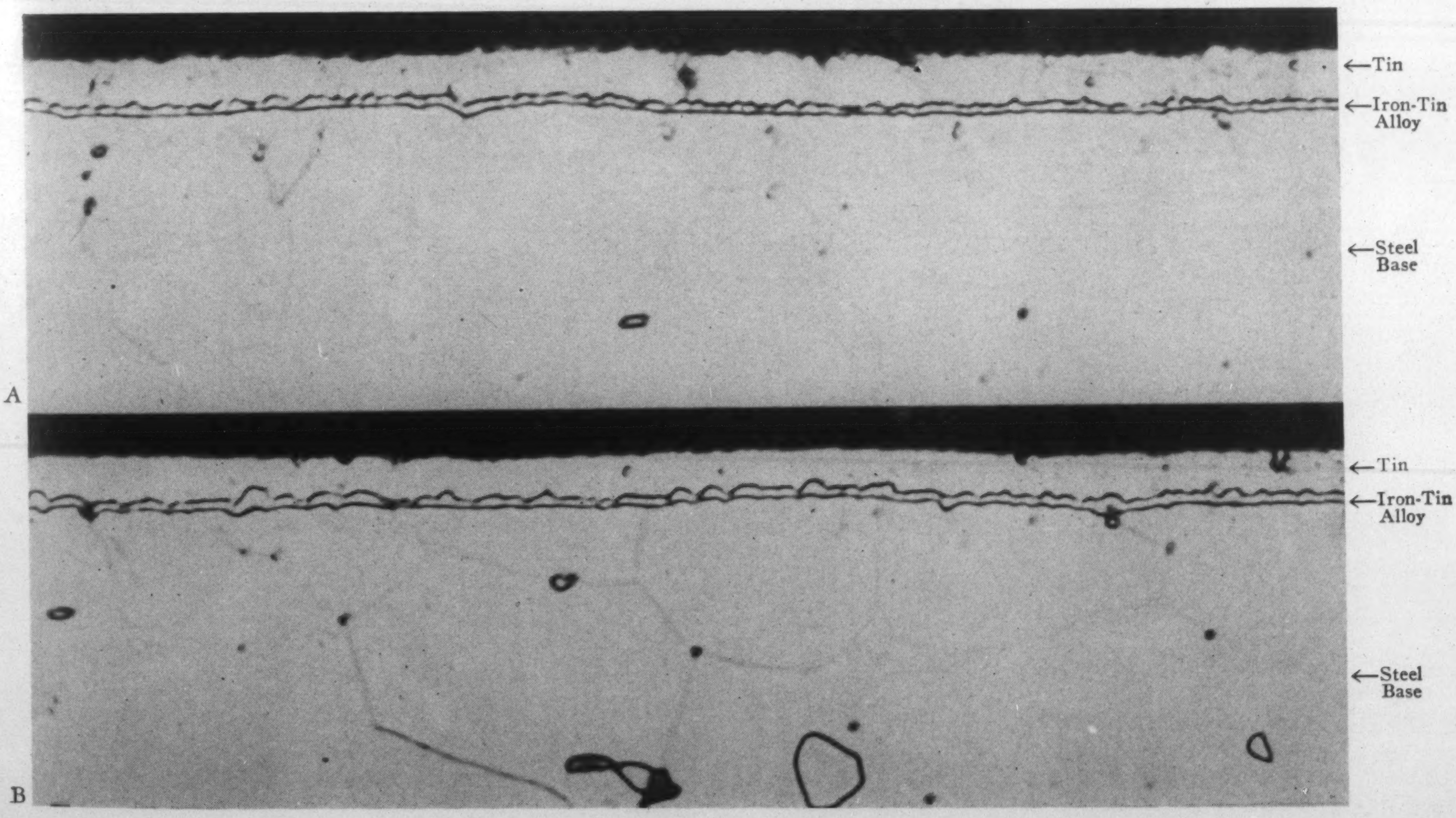


Fig. 5. Cross sections of coke tin plate after heating. Double etched to reveal iron-tin alloy layer. 2500X. (A) Heated 1 hr. at 400 deg. F.—average weight of coating 0.99 lbs. per base box. (B) Heated 2 hrs. at 400 deg. F.—average weight of coating 1.23 lbs. per base box.

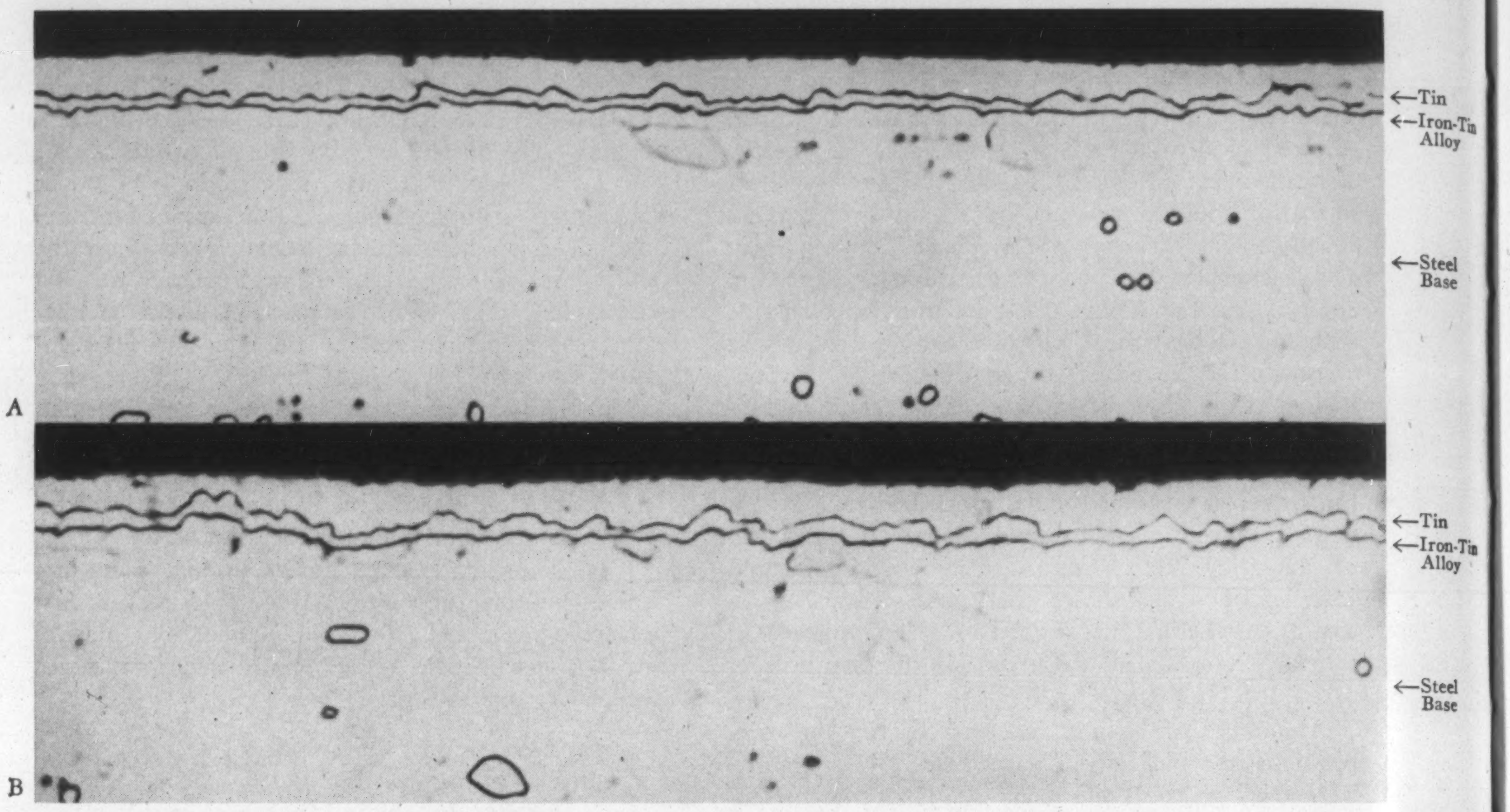
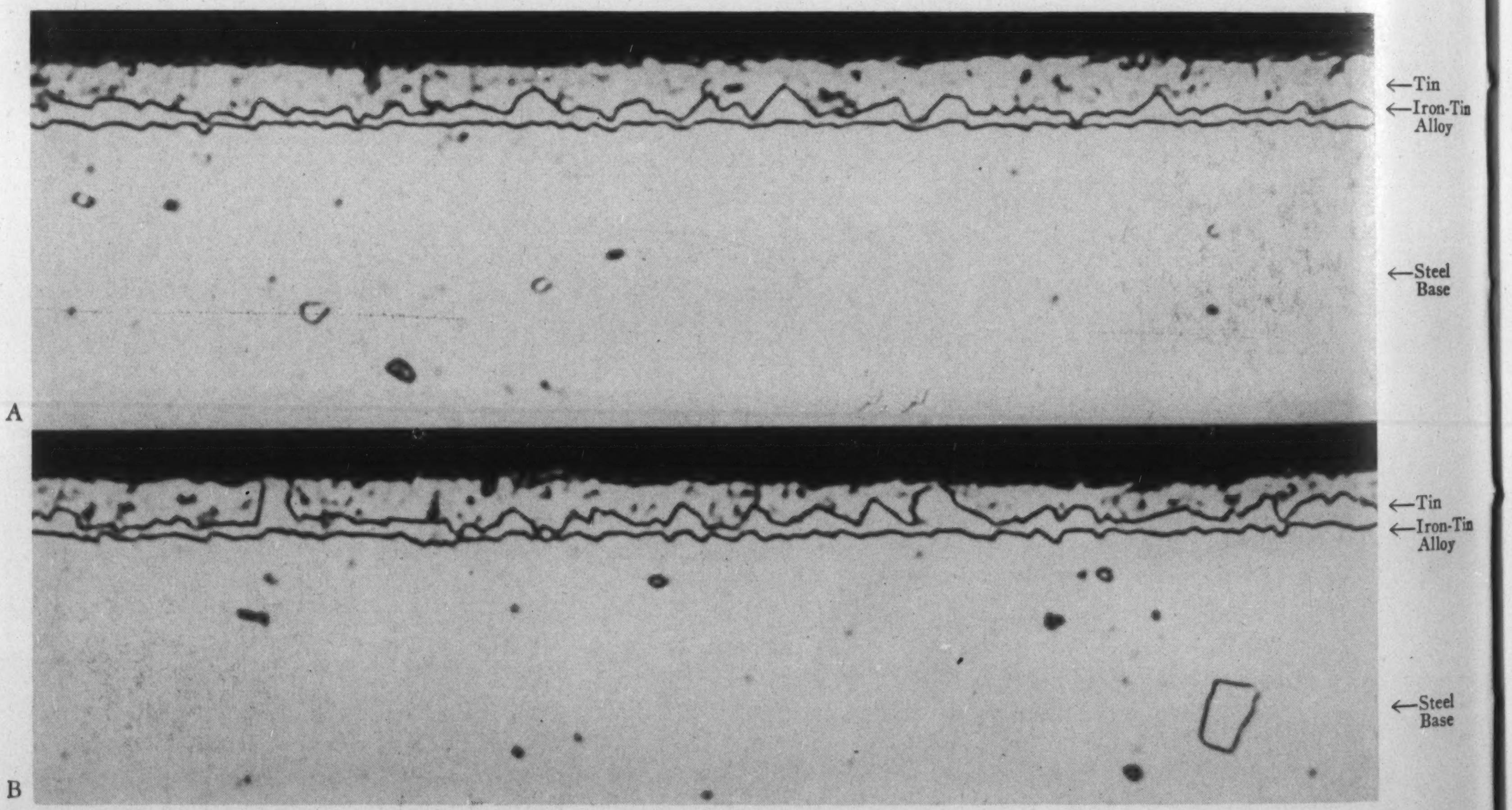

←Tin
←Iron-Tin Alloy
←Steel Base
A
←Tin
←Iron-Tin Alloy
←Steel Base
B

Fig. 6. Cross sections of coke tin plate after heating. Double etched to reveal iron-tin alloy layer. 2500X. (A) Heated 1 hr. at 425 deg. F.—average weight of coating 1.28 lbs. per base box. (B) Heated 2 hrs. at 425 deg. F.—average weight of coating 1.19 lbs. per base box.

Fig. 7. Cross sections of coke tin plate after heating. Double etched to reveal iron-tin alloy layer. 2500X. (A) Heated 1 hr. at 475 deg. F.—average weight of coating 1.41 lbs. per base box. (B) Heated 2 hrs. at 475 deg. F.—average weight of coating 1.20 lbs. per base box.


←Tin
←Iron-Tin Alloy
←Steel Base
A
←Tin
←Iron-Tin Alloy
←Steel Base
B

2. Mount between steel or bakelite end blocks held together by bolts—cellophane between each two successive specimens.
3. Surface grind to obtain flatness.
4. Hand grind on 0, 2/0 and 3/0 emery or carborundum metallographic papers.
5. Final grinding on vertical lap covered with 3/0 metallographic paper impregnated with graphite. Lap speed 1200 r.p.m.
6. Preliminary polish:
   (a) Tonerde (Trade name for a high-grade alumina described later) horizontal lap covered with high grade woolen broadcloth. Lap speed 300 r.p.m.
   Alternate polishing and etching necessary—steel base etched for 30 sec. in 5 per cent picral—tin coating remains unetched. Repeat process until tin coating is well defined and specimen is optically flat.
7. Final polish:
   (a) Tonerde on horizontal lap covered with high grade silk velvet. Lap speed 50 to 75 r.p.m.
   This is a polish of short duration intended to remove scratches remaining from the preliminary polish.
8. Etching agents to reveal iron-tin alloy layer on commercial hot-dipped tin plate:
   (a) Etch the specimen for 1 minute without agitation in a mixture of nitric and hydrofluoric acids in glycerine,

$$\left.\begin{array}{l}\text{1 drop HNO}_3\text{ (conc.)}\\ \text{2 drops HF \quad ''}\\ \text{25 ml. glycerine}\end{array}\right\}\text{ mix well}$$

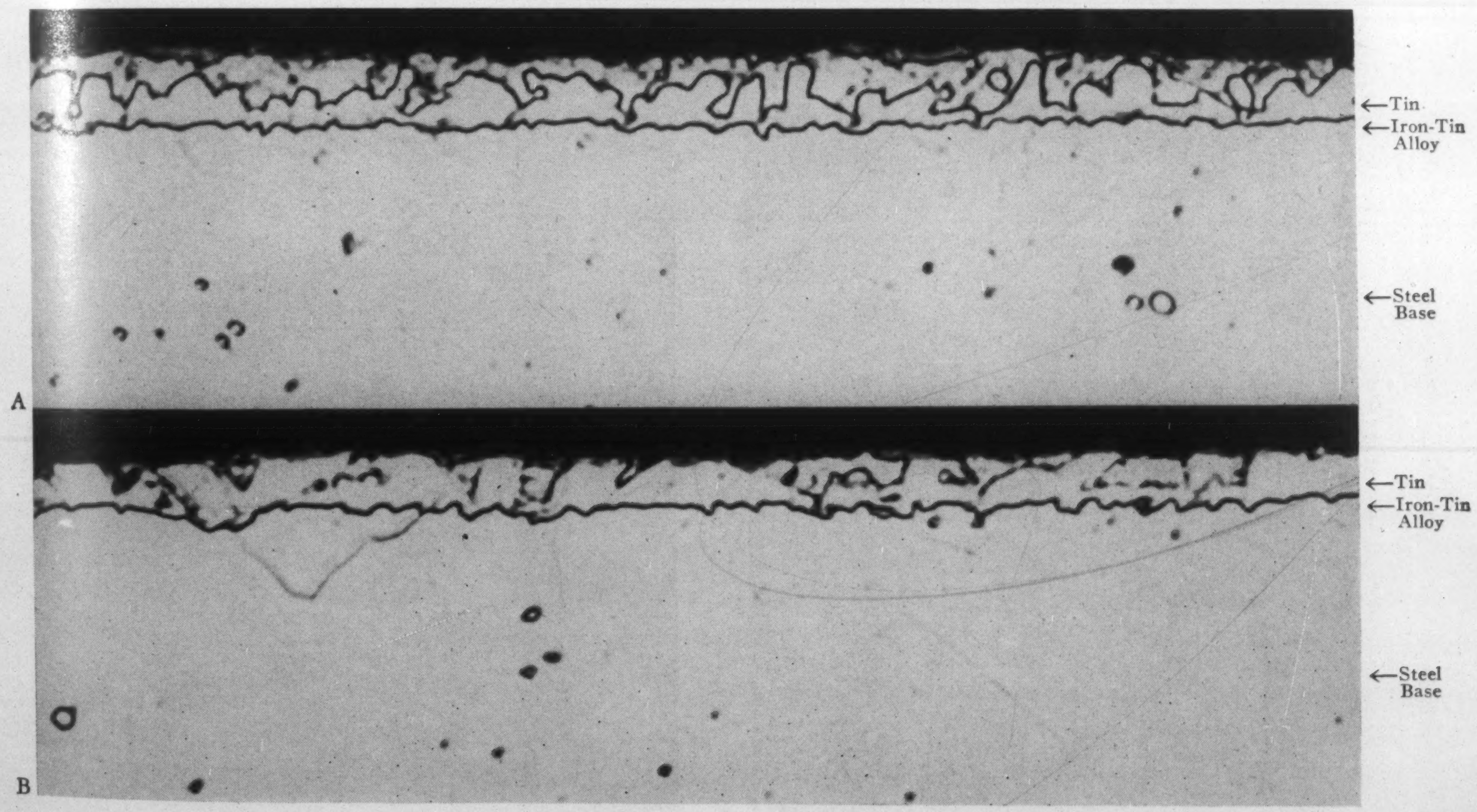
   (b) Alternative etching agent for heavy tin coatings and thick alloy layers:
   Etch for 3 to 15 sec. with agitation in a solution containing 1 drop of HF (conc.) per 100 ml. of absolute methyl alcohol.
   Temperature of etchants should be between 70 and 80 deg. F. These etchants reveal the tin side of the alloy layer.
   (c) To reveal the iron side of the alloy layer follow the above treatments by etching the specimen for 5 to 10 seconds in 5 per cent picral.

The double etch is necessary to show both sides of the iron-tin alloy layer.

To obtain a uniform thickness of lacquer, oversized specimens should be dipped, baked, and then trimmed to size. Sheet cellophane 0.001 in. thick designated as "300 MST" by the E. I. du Pont de Nemours & Co., Inc., Wilmington, Del., has given excellent results. When bolting the specimens together, care should be taken not to flow the tin, or cause recrystallization, by exerting too much pressure in the vise. The preparation of a few mountings will indicate the maximum vise pressure allowable.

Incidentally, the use of cellophane to stop seepage of etchants is applicable in the mounting of all

Fig. 8. Cross sections of coke tin plate after heating. Double etched to reveal iron-tin alloy layer. 2500X. (A) Heated 1 hr. at 550 deg. F.—average weight of coating 1.43 lbs. per base box. (B) Heated 2 hrs. at 550 deg. F.—average weight of coating 1.33 lbs. per base box.



sheet steel products, whether coated or not. This is especially true of specimens mounted in a bakelite press, since the cellophane partially melts at press temperatures and thus effectively fills voids between specimens.

After the specimens have been mounted, the next step is to secure a flat polishing surface. The use of a machine shop surface grinder is unexcelled for this purpose. Other means may be used, however, such as belt grinders, grinding wheels, or filing.

A flat surface having been obtained, hand grinding on 0, 2/0 and 3/0 emery or carborundum metallographic papers, in the order given, serves to prepare the specimen for the vertical lap. The final grinding operation, in which 3/0 graphite impregnated metallographic paper is used on a vertical lap, removes the need of coarse abrasive in subsequent polishing operations. The paper is impregnated with graphite by rubbing it with a piece of electrode carbon or its equivalent. The vertical lap is preferable to the horizontal type because it does not readily collect dust or grit.

When all of the scratches from hand grinding on papers have been removed on the lap, the specimen is ready for polishing. The polishing agent used in both preliminary and final polishing has the trade name "Tonerde No. 3." (Obtained from Conrad Wolfe, P. O. Box 448, Newark, N. J. This product is a patented German polishing agent and is not at present readily available. It is high grade alumina and although it has been found somewhat superior to similar American products, its specific use is not imperative.) A properly broken-in woolen broadcloth with a short pile is desirable for the preliminary polish. Alternate polishing and etching with picral as the etching agent is employed until the tin coating is well defined, each polish lasting only long enough to remove the effects of the preceding etch. Prolonged polishing between etchings is to be avoided since it causes beveling of the coating. Ordinarily, four or five polishings and etchings are sufficient if the specimen has been properly mounted and ground.

The final polish, on high grade silk velvet (black), is performed on a slow speed wheel using very little pressure on the specimen. This polish is of 5 to 10 min. duration and prepares the specimen for the tin etching reagents. A short etch of 5 sec. with picral prior to the final polish is recommended.

Up to this point, only the picral etching agent has been used, the object being to maintain the level of the steel base at or below that of the tin coating, thus effectively minimizing rounding of the coating during polishing. In the final polish the two are, of course, brought to the same level. As previously mentioned, five per cent picral does not appear to attack the tin coating.

The acid glycerine etching reagent for tin has been

Fig. 9. Etched coke tin plate surface. Average weight of coating 1.51 lbs. per base box. Etchant: Alcoholic acid ferric chloride. $^3/_4$X.

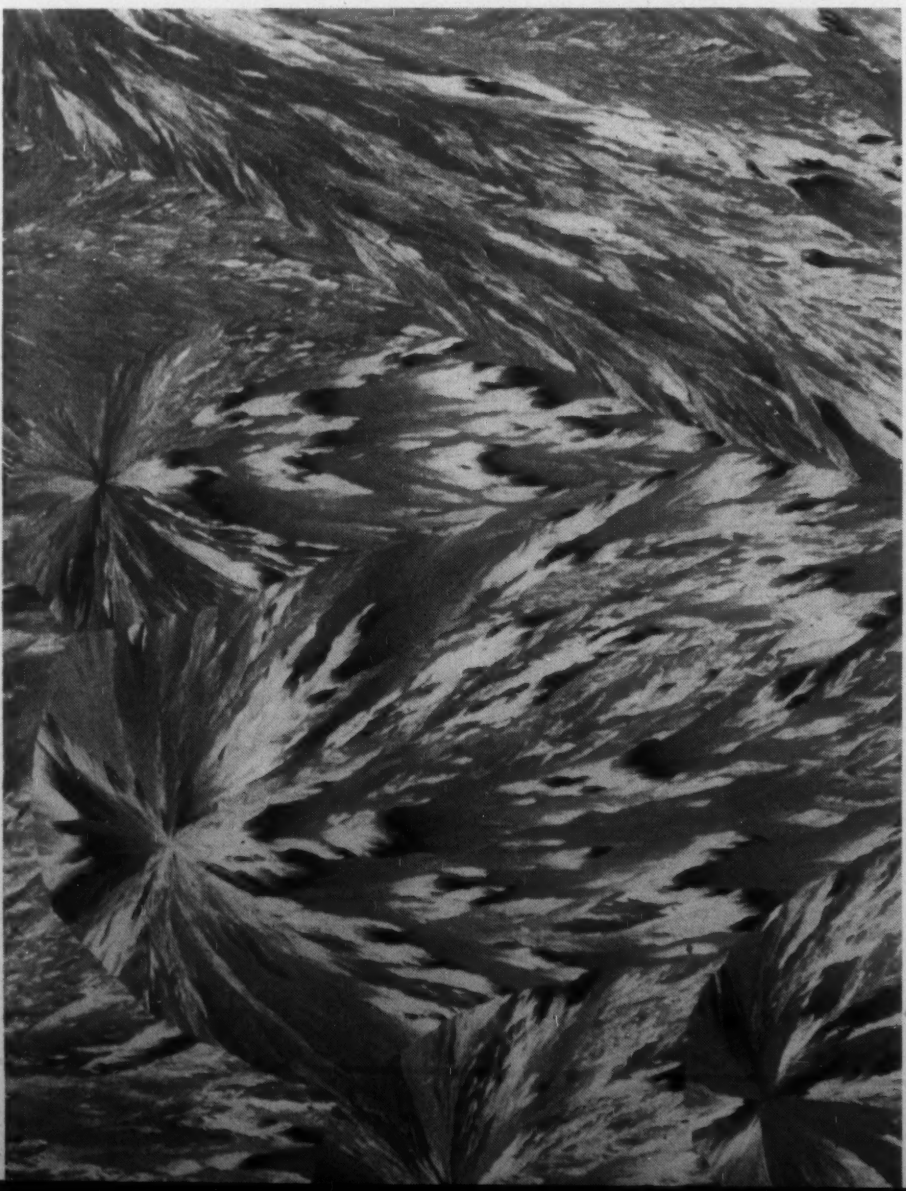
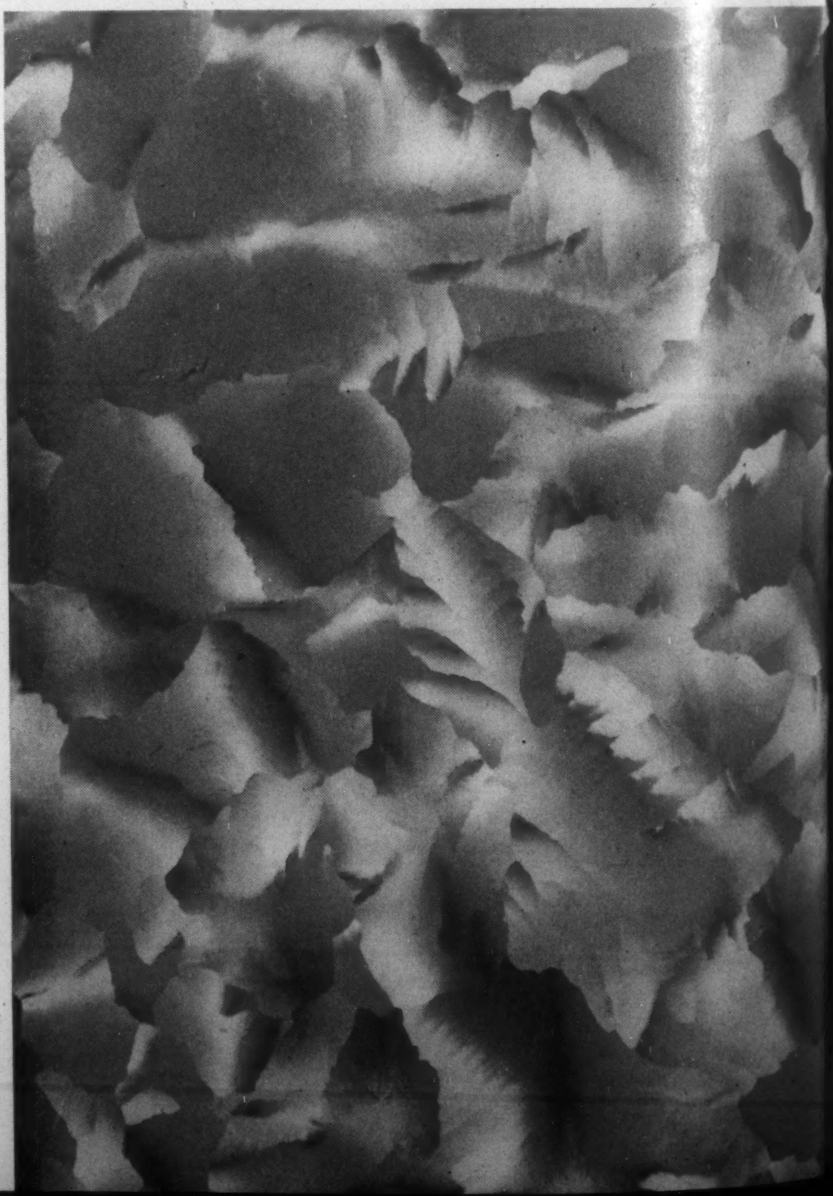


Fig. 10. Etched charcoal tin plate surface. Averag weight of coating 6 lbs. per base box. Etchant: A coholic acid ferric chloride. $^3/_4$X.



found to be rather critical in use. Staining and nonuniform etching may result with improper concentrations and etching temperatures. The picral etchant, however, is not critical as to composition and etching temperature but its application should follow rather than precede the acid glycerine etch.

A photomicrograph of a cross section of coke-grade tin plate prepared by the foregoing method is shown in Fig. 4. The iron-tin alloy layer is clearly defined. The photomicrographs of Figs. 5 to 8 inclusive are similar cross sections illustrating the growth of the alloy when specimens were subjected to temperatures of 400, 425, 475 and 500 deg. F. for periods of 1 and 2 hrs. in each case. The absence of any visible structure in the tin layer adjacent to the iron-tin alloy was attributed to one or more of the following circumstances: A relatively light etch; the structural characteristics of tin coatings on commercial tin plate; or, to the high magnification employed in obtaining the photomicrographs.

The surface structure of the tin layer on commercial tin plate can be easily revealed by any of the three above mentioned tin etchants. The ultimate result obtained through the individual use of these etchants is the same but the acid ferric chloride, mentioned under block tin, is to be preferred for this purpose because it etches the tin far more rapidly than the weaker reagents. The surface structures of two different grades of commercial tin plate are presented in Fig. 9, and Fig. 10. Variations in design are frequently observed but those exhibited are typical. That the structures shown in these photographs extend from the surface of the tin to the alloy layer seems probable since prolonged etching, even to complete removal of the tin, introduces no observable shifting or change in the pattern that was obtained at the surface. If, then, etching has revealed the true grain size of the tin, it must be concluded that the grain size of commercial hot-dipped tin plate coatings is quite large.

As far as the authors are aware, the grains or crystals apparent to the eye without magnification, as in Figs. 9 and 10, have not been resolved by microscopic examination into finer grains. This is true both for the surface or for cross sections of coke-grade tin plate which has not been mechanically worked or heated, or both. With grains of the magnitude shown, it seems doubtful that grain boundaries would be visible after lightly etching to reveal the extremely thin alloy layer and tin coating on cross sections of tin plate which necessarily require high magnification for adequate resolution.

It is believed that the technique described for the metallographic study of very light tin coatings should be of benefit to other investigators. It is hoped, therefore, that the future study of coating adherence, surface abnormalities, luster, forming qualities, and other related properties of tin plate may be materially aided by having at hand a method for revealing on cross sections the configuration and thickness of the iron-tin alloy layer.

Acknowledgment: The authors wish to express their appreciation to D. F. Armiento for assistance in the preparation of many of the specimens and photomicrographs and to others of this laboratory for advice, aid and helpful criticisms.

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(See letter to the Editor, page 449)

Hydrogen in Steel and Cast Iron—I

AND DEFECTS IN APPLIED COATINGS

by C. A. Zapffe and C. E. Sims

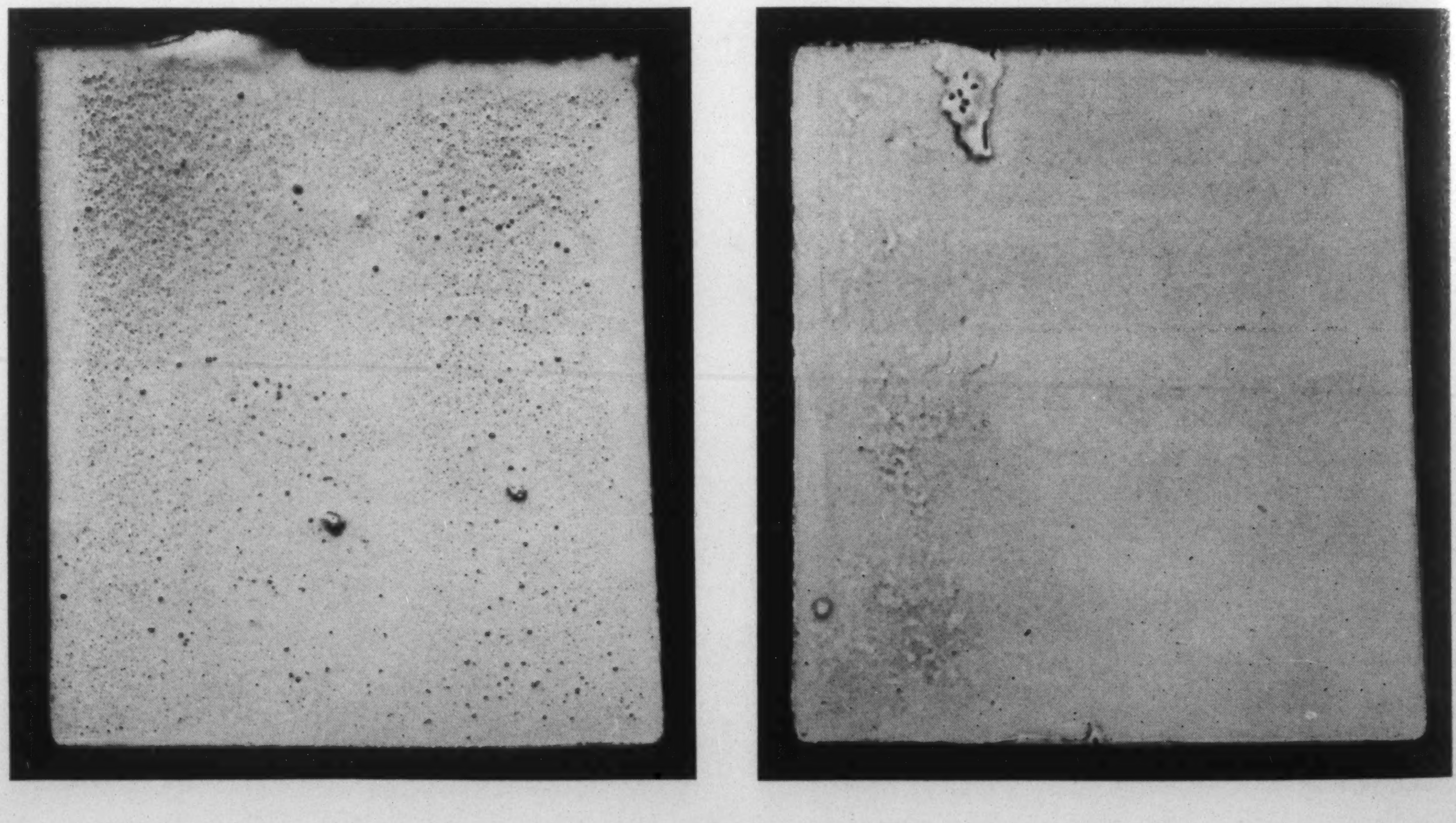
In the May, June, July and August issues of METALS AND ALLOYS, *last year, we published a correlated abstract by these authors on "Hydrogen, Flakes and Shatter Cracks" which attracted wide attention.*

In this issue we publish the first instalment of an article which discusses the effect of hydrogen in steel and cast iron on vitreous enameled coatings. Hydrogen absorption and hydrogen effusion at elevated temperatures as well as hydrogen absorption and hydrogen effusion at ordinary temperatures are reviewed in detail including the effects on applied coatings. The article has a great deal of practical value.—The Editors.

IN THE INTRODUCTORY PAPER on Hydrogen in Steel[1] it was concluded from preliminary observations that effusion of absorbed hydrogen from iron and steel must act to deface applied coatings—particularly vitreous enamel coatings. Since then, investigations at Battelle Memorial Institute have shown that many long-recognized but unexplained defects in resinous coatings, electroplated coatings, and vitreous enamel coatings on steel and on cast iron may be caused by hydrogen which has been previously absorbed by the iron or steel base.

These investigations have been published, but in non-metallurgical literature. Their significance to metallurgists warrants some discussion. (The original papers should be consulted for detailed information of tests that are only briefly treated here.)

Fig. 1. Chill-cast plates fired with vitreous enamel for 10 min. at 725 deg. C. (1340° F.). (Left) Iron made under hydrogen. (Right) Iron with hydrogen removed, showing complete freedom from pinholing.



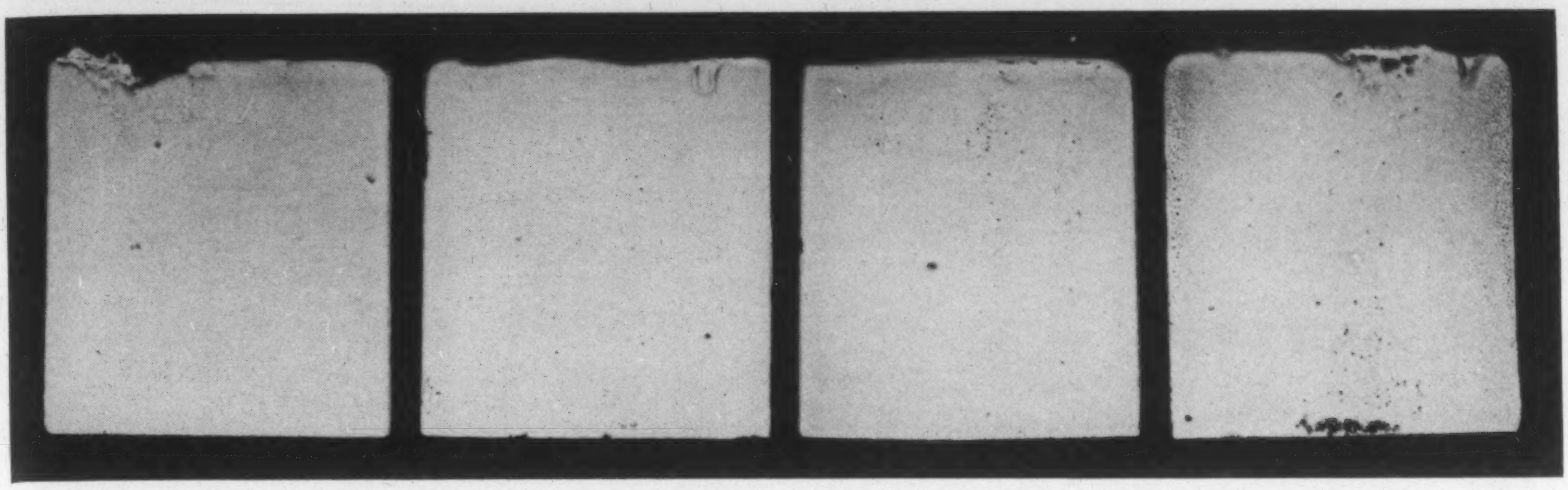


Fig. 2. Chill-cast plates prepared under conditions offering various degrees of hydrogen absorption and fired with vitreous enamel 18 min. at 725 deg. C. (1340° F.). No. 1, hydrogen removed; No. 2, ordinary melt; No. 3, scrap addition; and No. 4 hydrogen atmosphere. (Blemishes in No. 1 due only to irregularities in the surface of the iron.)

Hydrogen Absorption At Elevated Temperatures

During Melting

Role of Hydrogen in Cast Iron Enameling: Probably the most important single feature of hydrogen in steel and iron is that the gas so readily supersaturates. It is this supersaturation that causes the "flake" and the "shatter crack" and which also causes hydrogen ultimately to effuse from the specimen. When a coating such as paint, vitreous enamel or electroplate is applied to steel, effusion of the gas underneath the coating develops pressure that leads to defects just as pressure from internal effusion leads to flaking. Much less pressure is required, however, to deface a coating, so coatings are sensitive tests for hydrogen that has been absorbed by the metal.

Conversely, the many industries using steel or cast iron as a base for an applied coating require metal that is unusually low in hydrogen content. It is interesting to note that in the literature of these various industries,[5] the enameling industry in particular,[3] many observations are recorded that show relations between the steel-making process and defects in subsequently applied coatings that are identical with those relations now well recognized in the case of flakes and shatter cracks. In the case of cast iron, the same obtains, and it has been shown that large scrap additions, melting in rainy weather and casting in damp molds leads to enameling defects, although no satisfactory explanation has been forthcoming.

In the present work the fact was brought out that hydrogen is the gas principally responsible for blistering defects in vitreous enamel during firing. To find the effect of hydrogen absorbed during melting, cast iron was investigated. Standard enameling iron of the following composition:

	Per Cent
Carbon	3.60
Silicon	2.35
Manganese	0.70
Phosphorus	0.65

was melted in an induction furnace under conditions providing various sources for hydrogen absorption. Each melt was cast in (1) chill molds, consisting of bolted steel plates, (2) green sand molds, and (3) dry silica brick molds lined with alundum and baked at 875 deg. C. (1600° F.).

The first melt was made under hydrogen. The second was thoroughly flushed with carefully dried nitrogen before casting to avoid the presence of hydrogen. A typical chill-cast plate, fired with vitreous enamel at 725 deg. C. (1340° F.), is shown in Fig. 1 for each of these two melts. It is seen that carbon oxides, which have generally been assumed by enamelers to be the cause of pinholes and blisters, have played no part whatsoever in the present test, and that when hydrogen was absent, these defects did not occur. Furthermore, each set of test-plates had well-defined chill layers. A previous popular belief has been that decomposition of a "micro chill" layer during firing provides finely divided, active carbon which reacts with oxides and oxygen to cause blistering from carbon oxide gases.

Absorption during Ordinary Melting: A melt was made without treatment of any kind, but the weather was dry and an induction furnace carries a minimum of moisture and contamination. Consequently, just as in industry, defects occurred only spasmodically. Pig iron, which was used in the charge, contains a considerable quantity of hydrogen inherited from the blast furnace and subsequently becomes enriched in hydrogen by rusting reactions. If melting conditions do not favor hydrogen removal, defects may result from this source.

Effect of Scrap Additions: The tremendous quantity of hydrogen that can be liberated by a very small

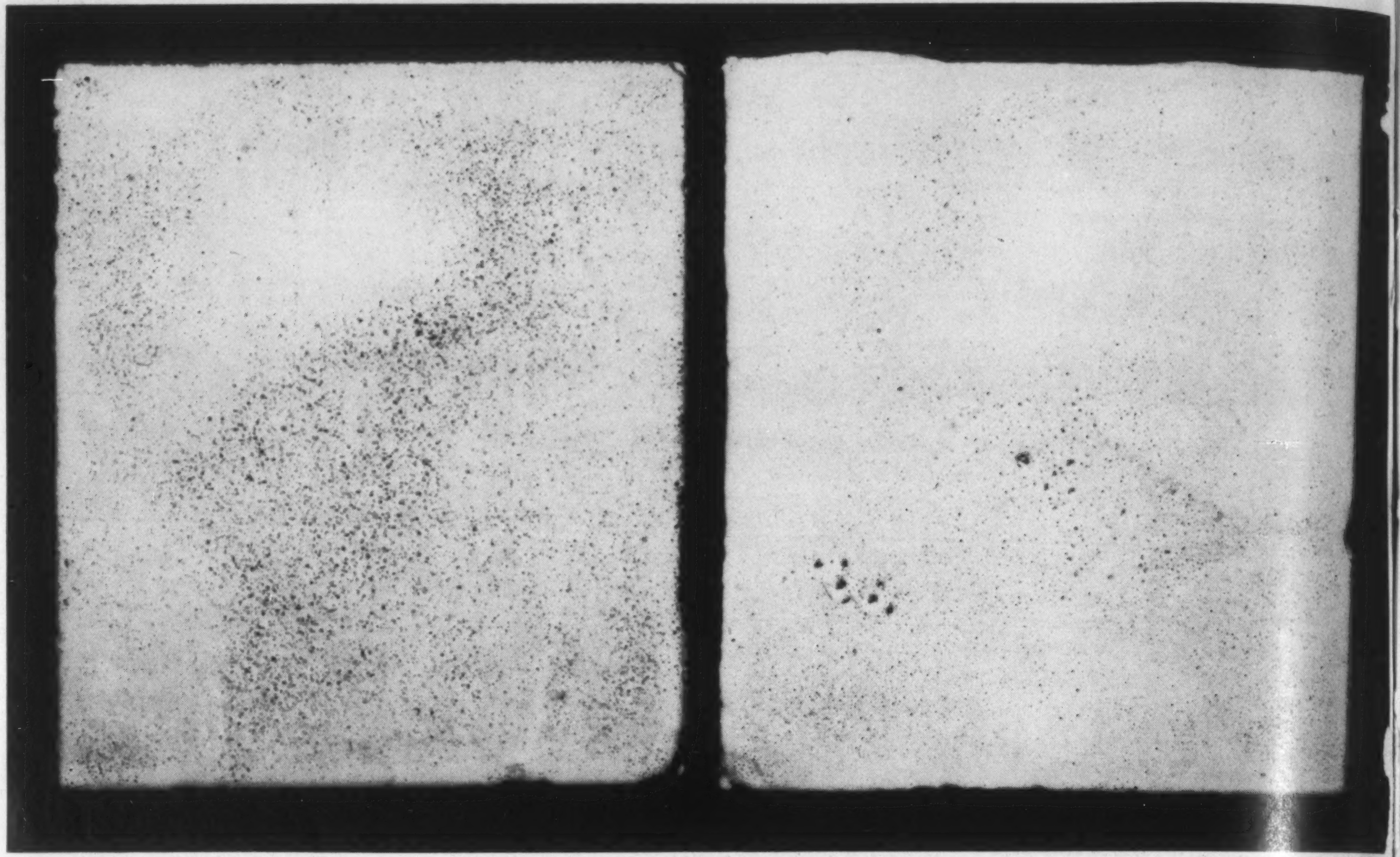


Fig. 3. Iron with hydrogen removed during melting subsequently cast in green sand molds. Fired with vitreous enamel at 725 deg. C. (1340° F.). Left: Fired 10 min. Right: Fired 18 min.

amount of water makes moisture the most important single source of hydrogen in iron and steel making.[6] Moisture carried by materials in the charge is especially dangerous, for the liberation of the hydrogen is likely to occur within the molten metal where all the gas is absorbed. Scrap not only carries a great deal of moisture in its rust, but the presence of the rust also implies that the scrap itself may contain a considerable quantity of hydrogen that has been supplied by the rusting reaction.

A melt was made with a 20 per cent addition of ordinary scrap, and blistering occurred during enameling.

A comparison of the degrees of hydrogen absorption in these tests is shown by the enameled surfaces in Fig. 2.

During Casting

That hydrogen is absorbed by cast iron during casting in green sand molds is shown in Fig. 3. The nitrogen-treated melt, which showed no blistering whatsoever when cast dry, provided specimens that blistered severely when cast in green sand.

During Annealing and Fabricating

Absorption of hydrogen from furnace gases during heat treatment is much more severe than is generally recognized. If the atmosphere is oxidizing to the iron, moisture is very likely present; if reducing, hydrogen-containing gases are probably present. In work to be presented elsewhere, it is shown that some ordinary furnace atmospheres are almost the equivalent of pure hydrogen in supplying this gas to steel. In vitreous enameling, the presence of reducing gases or moisture in the furnace atmosphere may lead to chipping after firing and to severe blistering during subsequent firing, each being due largely to effusion of the hydrogen absorbed from the furnace gases.

An especially elusive source of hydrogen in enameling has been that small amount of moisture, rarely more than 1 or 2 per cent, that is chemically combined with the clay in the slip. No matter how thoroughly the slip is baked at moderate temperatures, enough water usually remains to liberate deleterious quantities of hydrogen by reacting with the iron during firing. The specimen becomes charged with hydrogen during this first firing, and subsequent effusion of the gas may cause numerous types of enamel defects to appear.

Hydrogen Effusion at Elevated Temperatures

From Atomic Solution

It will be recalled that hydrogen may exist in iron and steel (1) in interstitial solid solution, (2) occluded in cavities and disjunctions as molecules, (3) occluded in inclusions as molecular hydrogen or compounds of hydrogen, and (4) chemically retained by molecularly dispersed impurities; and that each fraction behaves differently with respect to temperature.

If steel is pickled in acid, as it is in many commercial cleansing operations, temporary supersaturation of surprising magnitude can result. Most of this gas exists as atoms in simple solution and as molecules in slip planes[7] and can be removed by subsequent annealing treatment. (For more detailed information Reference No. 7 should be consulted.) If not removed, the gas can damage deep-drawing and other properties as is shown elsewhere.[1] Also, this dissolved fraction may cause enameling defects when the steel is heated and the diffusibility of the gas is suddenly increased. In a test in the present work[3] dissolved hydrogen from pickling was purposely not removed and a subsequently applied enamel coating was ruined by a continued gaseous effusion which caused severe blistering and lifting during firing and chipping after firing. Fig. 4 shows the effect of the baking period on removal of such dissolved hydrogen. The wedge was baked 30 min. at 115 deg. C. (240° F.) and fired at 870 deg. C. (1600° F.) with vitreous enamel. Thicknesses of the wedge up to 3/16-in. had been sufficiently freed of hydrogen during the baking period and the enamel over this area has a "boiled down" appearance.

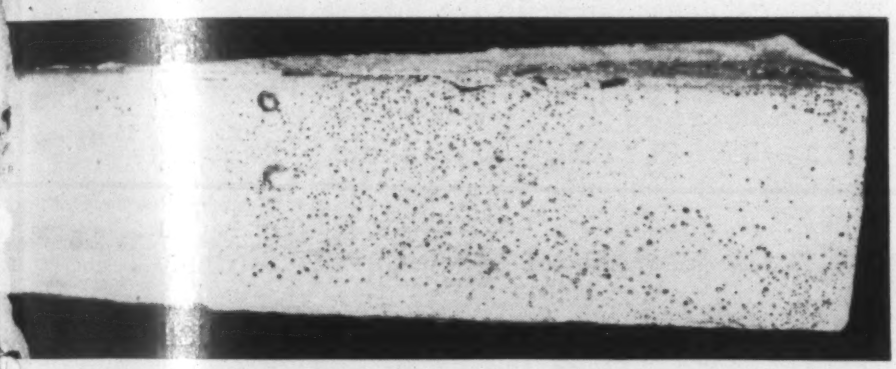


Fig. 4. Steel wedge cleaned by pickling, baked 30 min. at 115 deg. C. (240° F.) and fired with vitreous enamel 5 min. at 870 deg. C. (1600° F.).

From Molecular Occlusion in Cavities

The well known efficacy of aging and low temperature annealing for hydrogen removal unfortunately has been misinterpreted by many to mean that all hydrogen may be so removed. In the previous article[1] this misconception was discussed. Numerous difficulties in industry are due to those portions of hydrogen which do not respond readily to annealing. The behavior of occluded molecular hydrogen, for example, is shown in the following experiment:

A plate 2 by 6 by 3/16 in. was drilled as shown in Fig. 5. The holes were sealed and the plate was prepared for enameling in the standard manner by pickling. Hydrogen was absorbed and then occluded in the artificial cavities. Baking such a specimen can only serve to remove gas dissolved in the iron lattice; and some of that, of course, will also precipitate in the holes during baking. To insure removal of nearly all ordinarily dissolved hydrogen, the plate was baked for 1½ hrs. at 115 deg. C. (240° F.). Fired with ground and cover coats of vitreous enamel, the specimen is shown in Fig. 5. The occluded gas redissolved at the firing temperature, defaced the ground coat as it effused from the steel throughout three successive firings totalling 14 min. at 870 deg. C. (1600° F.), blistered the cover coat and then continued after cooling to effuse from the re-charged walls around the cavity until some of the blisters were exploded away. *(To be continued)*

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(Editorials—Continued from page 415)

ores, with a minimum of thought on development of domestic substitutes. The word "substitute" is beginning to creep into the official press releases, so perhaps the next logical step will sometime be made. That step would be to foster the international development of substitutes and their employment in actual service (without too great regard to the present economic position of the substitute) by means analogous to the "educational orders" that are applied to production problems.

The development of new technology applied to a substitute material often brings savings that could not be foreseen, and the economic picture is constantly changing. If the "know-how" is worked out, we are ready to move the moment the economic situation warrants. Stock-piling of knowledge as to substitutes, their production and utilization, would be as useful a defense measure as some of the more obvious ones. Air nitrogen is a good example. When its technology was being worked out during the World War, the effort was primarily on a military basis regardless of cost. Few engineers considered it possible that air nitrate could compete with Chilean nitrate on a peace-time, purely economic basis, but once the know-how was established and quantity production was achieved, it did become the cheaper. Like developments might occur in many other fields, once we have the know-how.—H. W. G.

That Old Proportional Limit

In a useful article in February *Product Engineering,* Hartmann deals with the use of fatigue test data in design calculations. In the course of discussing the effects of stress concentration he brings out the effect of a very tiny amount of plastic deformation in distributing stress that would otherwise be localized. In one particular case in the aluminum alloy 17 ST, a stress concentration factor of 2.4 holds as long as the action is truly elastic, but thereafter decreases considerably.

In this particular alloy and treatment, he takes the point of incipient plasticity at ¾ of the yield strength, remarking, "in aluminum alloys, as in many other metals, plastic action begins at stresses somewhat below the yield strength, and the ratio ¾ is fairly representative of the point at which this action is likely to become noticeable in the type of behavior under consideration." Using such a ratio may be a satisfactory approximation for a restricted class of materials, say for the strong aluminum alloys as a class, but to make that same approximation for an entirely different class of alloys such as work hardened 18:8 would be incorrect. So if one is to apply the general methods described by Hartmann to other specific cases, one must have the stress-strain diagrams for the other metals. In other words, we need information on some such degree of incipient plasticity as the old-time "proportional limit" determination purported to give.

This was discussed editorially in our June, 1940, issue, but the point deserves making again. Since we are quite as vitally concerned, in much engineering design, with the ability of a metal to give a very little very early, as we are with its ability not to give more than 0.2 per cent at some particular higher stress, should we not be paying much more attention than we usually do to the 0.02 per cent or even the 0.002 per cent yield strength?—H. W. G.

Youth and Age

On Feb. 18, the Editorial Advisory Board of Metals and Alloys held its annual dinner. We were all saddened by the news that our friend Paul E. McKinney was not expected to live. He died that night. Dr. Johnston remarked that with deaths, incapacities and retirements of the older group of metallurgists, the balance of influence is definitely shifting into the hands of the younger men, and that he himself felt that we must look to men in the 30 to 50 group rather than to those in or approaching their 60's for most constructive achievements.

It is true that metallurgy in the United States, as we know it today, arose in the lifetime and largely through the efforts of pioneers who are still living and of others who passed away so recently that many of those now active have personal memories of them; for example, of Howe, Campbell of Michigan, Campbell of Columbia, Sauveur and Moldenke. Though Metals and Alloys has not yet had a very long history, it had articles by the last three named. Of the Editorial Advisory Board of Metals and Alloys, Mathews, Bassett, Spring and Bull have passed on. All of these were active and productive, as was McKinney, right up to the end.

Not the least of the virtues of this galaxy was the personality of each, their farsightedness, their lack of self-seeking, their forthrightness in thought and expression, and their interest in the advancement of metallurgy. All were active in technical committee work, and in that work they were concerned with the long-time good of the industry, they never used their committee connections for the monetary advantage of their firms or clients. All of them came in contact with many younger men. These younger men took on some of the attributes that made the older group so admirable.

Dr. Johnston's comment seems to us to be true in a strictly technical sense, in that, since the days of training of the older group, a variety of new tools and new techniques have arisen with which the younger generation is familiar, but with which, because they have not personally carried out work of that type, the older generation is not familiar. Guidance of the youngsters by the oldsters must therefore be along broad lines, rather than in great technical detail.

But does not Dr. Johnston himself exemplify the best of what we have a right to expect from the oldsters? He may not be (though he probably is) up on the latest kink in calculating and plotting probability data, but he can certainly size up a problem as one likely to be solved by statistical attack, and set the youngsters to work on it. And his impatience with hasty conclusions, his insistence on real proof rather than half-proof and his habit of looking at things broadly, are of far more value to his staff and his firm than would be the ability to set up the latest electron tube circuit for some new and precise measuring device.

Indeed, the ability to look at things broadly is transmittable by example to a large number of colleagues and even casual acquaintances, while the teaching of mere technical details is a laborious and time consuming job for both teacher and student. McKinney's influence, for example, spreads far beyond the group at Bethlehem.

It is not hard to recognize the people who do look at things broadly. When a youngster has an opportunity to confer with, or to do committee work with individuals of that type, he should seize it, as a means to a very important part of his education. —H. W. G.

letters TO THE EDITOR

Failure of Low Carbon Steel Tubes

To the Editor: We have followed, with great interest, the letters discussing intergranular failure of low carbon steel tubes that have appeared in METALS AND ALLOYS during the past year.

We are inclined to agree with Mr. Moore (April, 1940, page 123) that intergranular failure of low carbon steel tubes is not unusual, and we wish to add a case to the record. The microstructure observed in connection with the rupture that has come to our attention is shown in the accompanying photomicrographs. Fig. 1 shows intergranular cracking adjacent to the rupture. Fig. 2 shows the general condition of the tube metal at the same location.

The failure occurred in a semiradiant superheater tube that had been in service for 18,151 hrs. and which normally operated at 620 to 650 deg. F.

As judged by the structure shown in Fig. 2, the tube metal temperature, at the rupture, must have been considerably in excess of 650 deg. F.—probably owing to a hot spot—because no difficulty has been experienced with the other tubes of the superheater. It would appear that the intergranular type of failure herein presented was due to increased temperature without increase in stress.

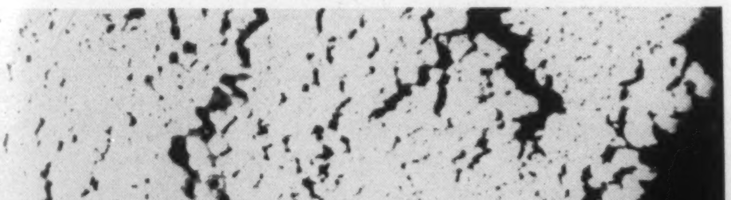


Fig. 1. Intergranular cracking adjacent to the rupture. Unetched. 100X.

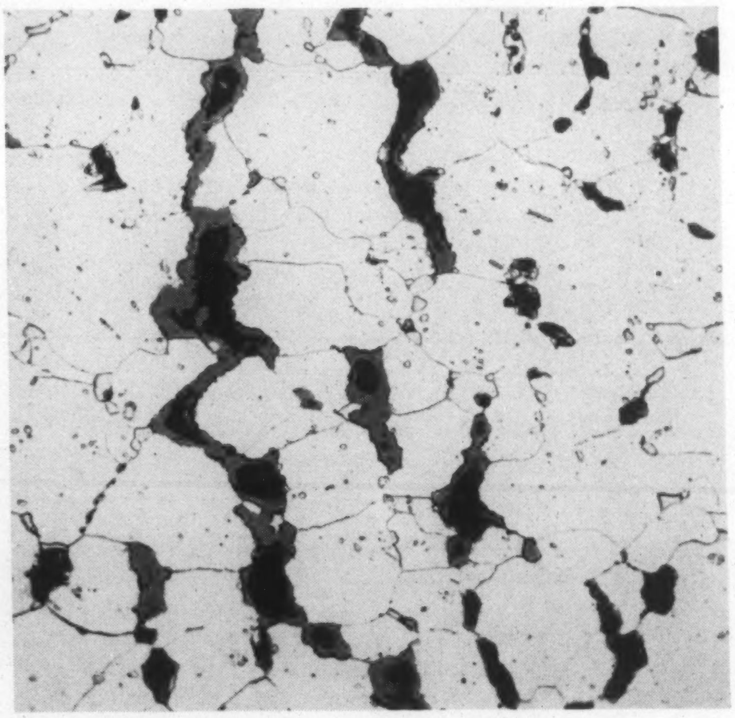


Fig. 2. Spheroidization of the structure and intergranular oxidation in the ruptured area. Etchant: 3 per cent nital. 500X.

GLENN COLEY
and
I. A. ROHRIG,
Metallurgist and research department, respectively

The Detroit Edison Co.,
Detroit

Metallography of Tin and Tin Coatings

A discussion of the article "Metallography of Tin and Tin Coatings on Steel," by O. E. Romig and D. H. Rowland

The necessity for a double etch to reveal the $FeSn_2$ phase in sectioned hot-dipped tin coatings would appear to indicate the existence of a progressive change of composition of the phase. Apart from purely mechanical disruption of the layer (exposing fresh surfaces for reaction), growth during annealing, found by the authors and previously by others,[1, 2] provides confirmatory evidence of composition gradients in the layer. It is interesting to note, however, that Ehret and Westgren[3] state that their X-ray photo-grams show a very narrow homogeneity interval corresponding almost exactly with the composition $FeSn_2$. Photomicrographs in the present paper show no indication of the existence of "FeSn" (B) or Me_2Sn (B') in the compound layer, and this confirms the writer's conclusions expressed in former communications.[2, 4] From purely theoretical considerations, however, other (high-iron) phases should exist in the structure under stable conditions. One may suggest that stable conditions are rarely obtained. It would be interesting to hear if the improved metallographical technique described here has succeeded in revealing such phases to visual observation if not to the camera.

1. Kohman & Sanborn: *Ind. Eng. Chem.* 1927, Vol. 19, p. 514.
2. W. D. Jones & W. E. Hoare: *J. Iron Steel Inst.*, 1934 (I), p. 273.
3. Ehret & Westgren: *J. Am. Chem. Soc.*, 1933, Vol. 55, p. 1339.
4. W. E. Hoare: *J. Iron Steel Inst.*, 1934 (I), p. 252.

International Tin &
Development Council
London, England

W. E. HOARE

Authors' Reply

Mr. W. E. Hoare's remarks regarding the composition of the iron-tin alloy layer in hot-dipped tin coatings are greatly appreciated. The authors agree with Mr. Hoare that from purely theoretical considerations alone other phases in addition to $FeSn_2$ should exist in the iron-tin alloy of commercial coke plate, but they have not as yet succeeded in revealing such phases. It is an interesting fact, however, that when polished cross sections of tin plate are dipped in a strong ammonium polysulphide solution, the alloy layer is not only etched, but non-uniformly so. Whether the non-uniformity of the etch is the result of concentration gradients, in the layer or the protective action of precipitated iron sulphide, has not been definitely proven. Further work is being done with this etchant and it is hoped that the results obtained may throw additional light on this problem.—(See Article, page 436)

18:8 and Notched Fatigue

To the Editor: This letter is in reference to the editorial "18:8 and Notched Fatigue" appearing in the December, 1940, issue of METALS AND ALLOYS.

The high notch fatigue resistance of 18:8 is justly emphasized and suggestions are timely as to greater use of this material in machine parts and especially when high stress concentration is involved. It is believed that this editorial is neglectful of the well-known, but too little used, principles of work hardening which may be applied to carbon and alloy steels as a means of greatly increasing their fatigue strength at points of stress concentration. The local cold working of fillets, notches and other forms of stress concentration is being practically used with beneficial results.

Since cold working phenomena are responsible for the favorable results with 18:8, as well as with carbon and alloy steels, it would only seem apropos to give the latter steels proper mention. Especially since local cold working of carbon and alloy steels costs so very little.

Chg. Ry. Engineering
The Timken Roller Bearing Co.
Canton, Ohio

O. J. HORGER

Granted. *But* we were talking about 18:8 rather than about the general topic. Double-subject letters are anathema, and double-subject editorials might well be. Cold working, as exemplified by shot-blasting of springs, is very effectively used on non-austenitic steels. But the relative response to cold work is even greater with the austenitics.—H. W. G.

Metals and Alloys in the Dairy Industry

To the Editor: In the excellent article by Dr. Trebler on "Metals and Alloys in the Dairy Industry" in your issue of December, 1940, reference is made to the fact that glass-lined or glass-enameled steel tanks for transport purposes have gone out of favour because of the difficulty of repair if accidentally cracked or chipped. This problem presented itself on one of the Railways associated in this Laboratory some time ago and it was overcome successfully by making good the places where the glass lining was chipped or perforated with pure tin applied by means of a metallising spray pistol. It was found necessary to sand-blast first in order to get a tooth on the glass round the perforation and to secure proper adhesion to the steel below; without this precaution the deposited tin simply lifted off again quite easily. Tanks repaired in this way have been in service now for more than a year and are still giving every satisfaction.

H. N. BASSETT,
Joint Chemist

British Argentine Railways Committee,
Central Laboratory,
Buenos Aires, Argentina

A Poem

To the Editor: A student engineer usually has a difficult time writing such things as letters of application. In a moment of relaxation during the process of concocting a suitable letter, I wrote this little poem which stated what I would like to say if *they would only believe it!*

A fellow student urged me to send it to you. So here it is:

A Metallurgist's Letter of Application

Do you want a man who's plenty hot
At tossing alloys in the pot?
Who knows his bricks from quartz to clay?
And one time damn near got an "A"?

Who'd scare the phos into the slag?
(And though he wouldn't like to brag),
Could cut down grain size in a casting
And make a metal really lasting?

To whom corrosion would be no puzzle
For he would quickly put a muzzle
On Profs and Docs and other guys
Who still think we can't metallize?

Well I'm the guy you've waited for
I'll work for you from eight to four,
Increase production so much more
Than you have ever seen before.

I'll raise your stocks and bonds so high
That they will tower in the sky!
And riches, glory, fame, will be
All yours, if you'll just hire *ME!!!*

ROBERT L. NICHOLS

727 15th Ave., S.E.
Minneapolis, Minn.

B. Met. E. '41
Univ. of Minn.

Live and Learn! — A Chuckle

Our attention has been called to a paragraph in a brief article on—"The Vending Machine"—in a house organ—"The Thread of Life"—of the State Mutual Assurance Co. of Worcester, Mass. From the description of the machine the following is cited by John M. Clauser of the Midvale Dental Supply Co., St. Louis:

> "The machine, however, holds its own fairly well, and is often more than a match for the human experimentalist. The dropped coin is subject to many tests before it is finally accepted. There are *magnets which divert copper and brass*, there are 'bouncers' which refuse to pass lead, and finally, there is a 'feeling wire' which will not pass a smooth slug but will accept a genuine coin upon which the proper reliefs have been impressed at the mint." (Italics supplied)

METALLURGICAL ENGINEERING news

Equipment
Finishes
Materials
Methods
Processes
Products

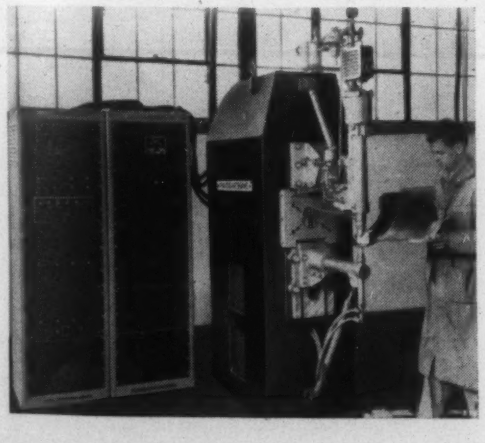
Alloys
Applications
Designs
People
Plants
Societies

Welding and Gas Cutting

All modern fabrication methods are today undergoing considerable evolution in the direction of increased speed—foundry engineers are "mechanizing" their operations to the utmost; forging shops and departments employ bigger, faster presses, longer-lived dies, higher-production heating methods, and welding processes are being made more efficient through the development of better methods and equipment for resistance welding, arc welding, gas welding and gas cutting. Some very recent innovations in the welding field are described in the following paragraphs.

Spot Welding of Aircraft Aluminum

A new high-speed production process for spot welding aluminum alloy sheets for aircraft has been announced by *Progressive Welder Co.,* 3050 E. Outer Drive, Detroit. The process is said to be based on a new operating principle and to produce welds in aluminum alloy with uniformity comparable to that attained in the production welding of steel.



The new process is claimed to involve no costly or complicated "energy accumulators," to obviate special skill on the operator's part, to produce welds entirely free from cracks and blowholes, and to yield joints of strength well in excess of government specification.

The principle of the new process is based on the use of all three phases of 3-phase alternating current, with the proper wave form developed in such a manner as to permit accurate control of welding current. The current is passed through a converter (which eliminates the negative portions of the waves), and the resulting pulsating current with a 300 deg. time cycle is passed through the welding transformer and gives a secondary current wave form that is ideal for aluminum.

The flexibility of the equipment permits the spot welding of aluminum sections totaling ¼ in. down to the thinnest weldable sheet on the same machine. The chief problem in the welding of aluminum—supplying sufficient current to do the work for a very short interval, is believed to be solved by the new method.

New Resistance-Welder Tube

A new ignitron tube, type GL-415, for resistance welder control, developed by *General Electric Co.,* Schenectady, N. Y., utilizes a unique water cooling system. The water jacket construction formerly used for such tubes has been replaced by a special plate into which the tube is fitted and which serves as a combination cooling medium and cathode connection.

The plate consists of a brass block with water passages through it. Because there are no water connections to the tube itself, the latter may be removed and replaced very easily. The new tubes' ability to pass high peak currents makes them ideal for current-control of resistance welders. A pair of these tubes can control two 260 k.v.a. on a 5½% duty cycle.

New High-Strength Electrode

A shielded arc type of electrode specially designed for welding high-carbon or alloy steels that are to be machined and flame-hardened or heat treated is now available from *Harnischfeger Corp.,* 4513 W. National Ave., Milwaukee. The new electrode is called "Harnimoly" and joints made with it are not only easily machinable in the as-welded state but have strong and uniform response to flame-hardening and heat treatment.

The physical properties given for the electrode are 85,000-90,000 lbs./in.^{2} tensile strength, 65,000-70,000 lbs./in.^{2} yield point, and 15-20% elongation in 2 in. Flame hardening will develop a weld metal hardness of 415 Brinell, it is said.

Riser-Cutting Apparatus

For the convenient removal of riser heads from metal castings, *Air Reduction Co.,* 60 E. 42nd St., New York, has introduced a new line of manual cutting apparatus comprising 2 torches and 3 tips.

The new torches, styles 3180 and 9080, are of the straight-head type. Each is 21 in. in length and cutting oxygen can be controlled by either a lever or trigger. The new types are, respectively, bent to 75 deg., bent to 90 deg., and without bend. The new types are said to feature greater maneuverability in cramped quarters.

This new apparatus is also applicable for the removal of rivets, for construction and repair jobs in shipyards, and for standard hard torches for general use.

● The flame hardening of castings has often been complicated by the problem of water quenching, and cast iron analyses have been sought that would flame harden on air cooling. Acme Foundry Co. of Detroit has evidently found this in a chromium-molybdenum iron (called by them "Hi-Tensilloy"), which can be flame hardened without a water quench to meet a specification of 460-600 Brinell. The iron contains 3.30% total C, 1.60 Si, 0.50 Cr and 0.30 min. Mo, and is used for large drawing dies and similar castings, reports *Climax Molybdenum Co.,* New York.

Metals in a New Coffee-Maker

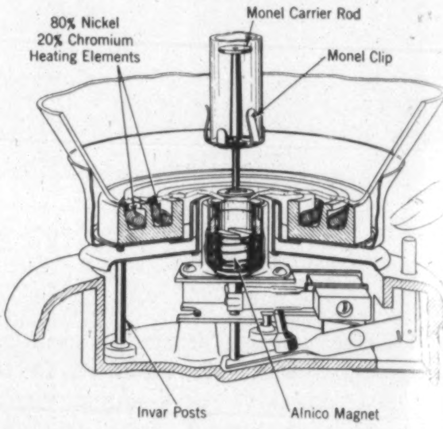
The vital importance of metals, and of special engineering knowledge of their versatile properties, in the design of modern electrical appliances is clearly demonstrated by the new electric coffee-maker developed by *General Electric Co.*, Bridgeport, Conn. The design of such a unit involves problems of selecting materials for heating elements, contacts, switches, magnets, posts, rods, thermostat bi-metals, springs, fastening, base, plated surface, etc., and entails familiarity with steels, stainless alloys, nickel alloys, copper alloys, light metals, plastics, finishes, etc.

Some ingenious design features depending on the use of special nickel alloys are cited by the *International Nickel Co., Inc.*, New York. Thus, the fully automatic performance of this new glass-bowl vacuum-type electric appliance is made possible by a magnetic switch located within the electric stove and operated by a powerful but exceptionally small permanent magnet made of Alnico (aluminum - nickel - cobalt - iron alloy).

Within the siphon tube inside the bowl is a Monel metal connecting rod, with a pure nickel disk at its lower end serving as the magnet's armature; a Monel disk riveted to the upper end serves to lift all three pieces at the proper time.

Thus, when the starting button is released, the Alnico magnet is freed to be pulled up by magnetic attraction to the nickel disk, even though the glass bottom of the bowl separates them. When the heated water in the lower bowl finally develops enough pressure to rush with a tremendous surge up the siphon tube, it pulls the disk assembly up with it; the Alnico magnet, its magnetic support gone, drops and shuts off the current.

The pure nickel of the armature not only contributes its non-corrodibility but has the exact magnetic qualities required for this device, and is said to permit greater variation in bowl thickness than when iron armatures are used. The invar (nickel-iron alloy) posts, with their low rate of heat transfer aid in preventing overheating of the plastic base.



Monel spring clips are used for fastening the strainer, because of their flexure-resistance, corrosion resistance and non-scratching effect on glass. Nickel-chromium heating elements, of course, are selected for longest life, temperature uniformity and cycle-by-cycle dependability in this fast heat, high-current-capacity application.

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Automatic Bending Machine

A new power-driven automatic bending machine, manufactured by *Parker Appliance Co.*, Cleveland, will be shown for the first time at the forthcoming A.S.T.E. Machine & Tool Progress Exhibition. This machine is designed primarily for bending copper and aluminum alloy tubing up to 3 in. O.D., and annealed steel tubing up to 2½ in. O.D. It is also applicable for bending equivalent structural shapes.

The machine operates in 2 automatic cycles—bending and return. Change-over from left to right hand bending can be made quickly. Production of 250 right-angle bends per hr. is said to be easily maintained on this new machine.

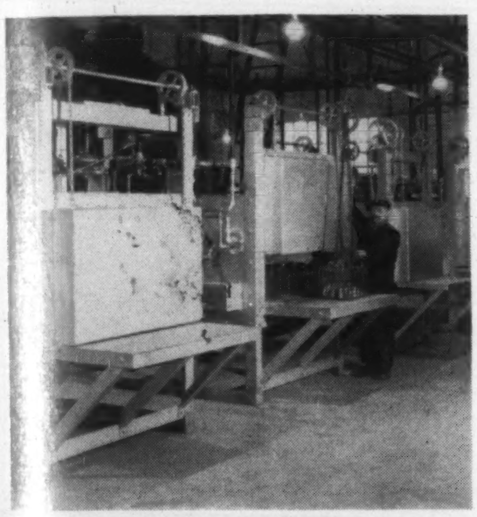
● To increase the number of "pushes" between successive redressings on extrusion dies, one large plant is using colloidal graphite as a lubricant in making extruded architectural and other shapes of aluminum alloys, reports *Acheson Colloids Corp.*, Port Huron, Mich. Life between redressings has been extended 20% and an improved product surface with reduction in scrap has been obtained.

Gas-Fired Non-Scaling Furnace

According to *Trent Engineering Laboratories,* 316 No. 22nd St., Philadelphia, the Wall-Trent Model W furnaces are oven-furnaces designed to give rapid, scale-free heating through efficient circulation of the products of combustion in the furnace.

The construction of these furnaces is such that a number of burners are fired underneath the arch and discharge the products of combustion at the bottom of the hearth on the same side. The furnaces are designed for any heat treating operation from 400 to 1800 deg. F., with higher temperatures available through changes in burner size and insulating refractory.

As indicated in the illustration, the furnaces are sturdy, being built around a heavy steel framework. The best quality insulating refractory is used for the furnace interior, backed by a low-heat-conductivity block permitting very rapid heating-up.



The air-gas ratio can be set to produce a reducing or neutral atmosphere, and prevent scaling. No flame impingement is possible with correctly-loaded furnace.

● Printing Plates Research, Inc., has launched a 3-year research program to be conducted at *Battelle Memorial Institute,* Columbus, Ohio. The purpose is to develop new products and new uses for the manufacturing facilities of the electrotype and stereotype foundries associated with the letter-press field of printing. B. W. Gonsor and R. M. Schaffert will direct the program at Battelle.

New Roofing Sheet Lead

An improved type of roofing sheet lead for which are claimed the advantages of lighter weight, greater tensile strength, lower installation cost, and reduced tendency to creep, has been introduced by *Revere Copper & Brass, Inc.,* 230 Park Ave., New York.

The new sheet lead roofing, known as "Roofloy," is made from the purest pig lead strengthened by judicious additions of calcium, magnesium and tin. These elements so improve the mechanical properties that the sheet can be rolled and used in thinner sheets than has heretofore been possible for such applications, it is said.

The creep resistance of Roofloy is claimed to be more than 10 times that of ordinary commercial sheet lead, and to be stable up to 180 deg. F. Because of this, failures from creep can be obviated, and this factor, together with the material's greater tensile strength, permits the use of Roofloy in much thinner sheets than ordinary lead, with a consequent saving in weight.

Although on a pound-for-pound basis Roofloy costs more than ordinary lead, the material cost for a job is always smaller with Roofloy because less of it need be used. It can also be used on steeper slopes than those considered safe for ordinary lead.

● According to the *Standard Steel Spring Co.,* Coraopolis, Pa., the Corronizing method of surface coating provides a means for conserving vital metals, such as zinc. Thus, zinc for plating requirements can be reduced 90% without sacrificing corrosion-resistance or durability through the use of the new electrolytic process, it is said.

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ALTER EGO: Literally "one's other self"—the still, small voice that questions, inspires and corrects our conscious action.

ALTER EGO: Certainly the Whizz Electrode demonstrator showed you speed *almost* as good as with "Fleetweld."

But the speed really was good, and the weld looks OK.

ALTER EGO: Yes, but, most of all, the *demonstrator* was good. How about the *conditions* of the show?

Come to think about it—it was just a show.

ALTER EGO: Right. 'Twas the work of a good, biased demonstrator. What counts are the results of our own men—the SPEED and QUALITY *they* can attain and maintain under *production* conditions—hour after hour—day in and day out.

Well, isn't "Fleetweld" just the ticket for that? What are we waiting for?

★ ★

LINCOLN SUGGESTS: Study of welding production methods often increases speeds as much as 50% through the use of work positioning, revised technique or better types of electrodes. The "Procedure Handbook" ($1.50 postpaid) on page 210 contains valuable information on this subject. Or perhaps the Lincoln man nearby can be of service to you. No obligation, of course.

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LINCOLN "SHIELD-ARC" WELDING THE LINCOLN ELECTRIC COMPANY
Cleveland, Ohio
Largest Manufacturers of Arc Welding Equipment in the World

New Metal-Spray Gun

A new type of metallizing gun has been developed for metal-spraying—a process that is growing in use for repairing and building up cracked or worn shafts, rolls, machinery parts, casting, etc., and for the application of corrosion-, heat- or wear-resistant metal coatings.

The new gun, called the Type 2E Metco metallizing gun by its manufacturer, *Metallizing Engineering Co.,* Long Island City, N. Y., has 2 outstanding new features—the "controlled power" unit, which gives an absolutely uniform and steady wire feed, and eliminates the need for gear changes; and the "universal gas head," which allows the use of acetylene, propane, hydrogen, natural or manufactured gas with balanced pressures and without changing heads.

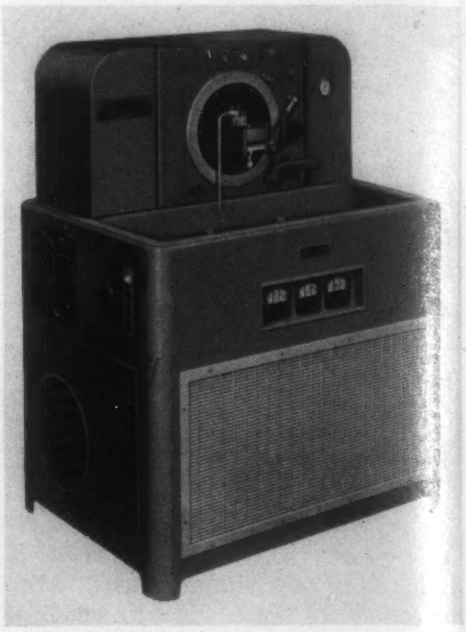
The metal wire is automatically fed into the gun at an adjustable speed, where it is melted in a concentrated flame, atomized by compressed air and sprayed on any base material. The gun may be used either as a hand tool for large structures or as a lathe tool for building up shafts, rolls, pistons, etc. Any metal obtainable in wire form may be used as coating material.

The new gun also has improved spraying characteristics—extremely fine coatings are obtained at production speeds, and continuous operation without sacrifice of quality is thus possible. Improved nozzle and jet construction reduce gas consumption. The maximum air pressure required is 65 lbs. per sq. in. The gun is said to be light in weight but rugged in construction.

Induction Heater for Small Parts

Plants in which the installation of elaborate heat-treating equipment is not warranted, yet which recognize the engineering advantages of induction heating will be interested in the new, streamlined Tocco Utility Junior machine of 20 kw. (output) capacity, just announced by the *Ohio Crankshaft Co.,* 6600 Clement Ave., Cleveland.

Specially designed for heat treating small parts, the new unit sells at a new low price and is offered in 2 models—one for applications not requiring quenching, and the other for localized Tocco-hardening. In the hardening machine (illustrated) a transformer housing and work pan have been added to the otherwise flat-topped basic 20 kw. unit. Both models use the same high-frequency motor generator sets, supplying 9600 cycles of high-frequency current at 220 v.



The variety of small parts that can be heated or surface-hardened on these units is said to be unlimited. Fixtures and coils are designed to meet user's specifications. Power consumption is described as extremely low.

- A two-tube laboratory combustion furnace is now being manufactured by *Harry W. Dietert Co.,* Detroit, in addition to the previously-announced single-tube combustion furnace under the Varitemp trade mark. The furnace, which is heated by 4 Globar heating elements, will produce a maximum temperature of 2750 deg. F.

- *National Gypsum Co.* has announced the purchase of the assets of the General Insulating & Mfg. Co., makers of Gimco rock-wool products and insulating material.

ELMET

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Our Contribution to the National Defense Program

A new procedure for manufacturing machine parts direct from powder by pressing and sintering, with qualities equal to other methods, to overcome shortage of skilled labor and machine tools.

Our experienced staff is at your disposal for all problems connected with powder metallurgy of iron and other metals.

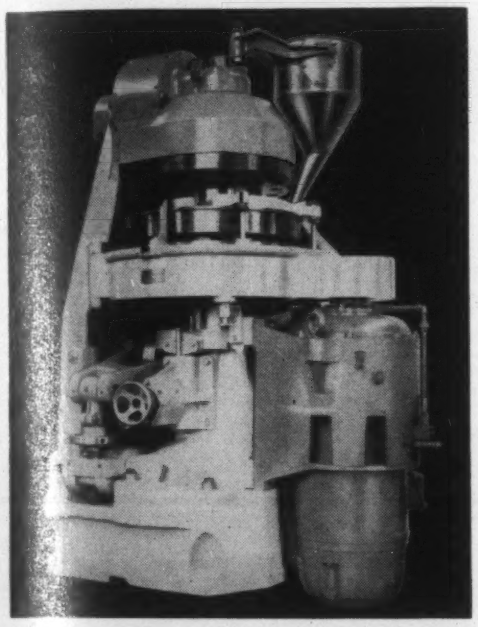
AMERICAN ELECTRO METAL CORPORATION

RESEARCH LABORATORIES AND OFFICES
320 Yonkers Ave., Yonkers, N. Y.
FACTORY
Lewiston, Maine

● A new, low-cost, general-purpose timer, capable of providing accurate automatic timing control for virtually any operation requiring cycling or sequencing in seconds or fractions of seconds, is announced by *Weltronic Corp.*, 3071 E. Outer Drive, Detroit. The new device operates on the electronic principle.

Powder Metallurgy Presses

New and larger rotary tablet compressing machines applicable for compressing oilless bearings, iron magnet cores, valve seats, small iron gears, pump seal rings, motor brushes and many other products of powder metallurgy are offered by *F. J. Stokes Machine Co.*, Philadelphia.



The new machines are capable of applying 30-ton pressure and producing parts with a maximum diameter of 2½ in. Each machine has a maximum die fill of 4 in., is arranged for making cored and special-shaped pieces, has 10 sets of punches and dies, and applies pressure to both top and bottom simultaneously.

The new machines are very rugged and stand 8 ft. 4 in. high. A patented combined pressure release is provided to spill overloads and prevent jamming or breaking. The output of the machine is 150 pieces per min. with all punch and die sets in use.

● More than 20 tons of copper sheet was used for expansion joints and water seals in the tunnels of the new super-highway, the Pennsylvania Turnpike, which connects Harrisburg and Pittsburgh. Additional tons of copper-silicon alloys were used for electrical conduit, bolts, angles, pipe supports and other applications, reports the *Copper & Brass Research Assoc.*, New York.

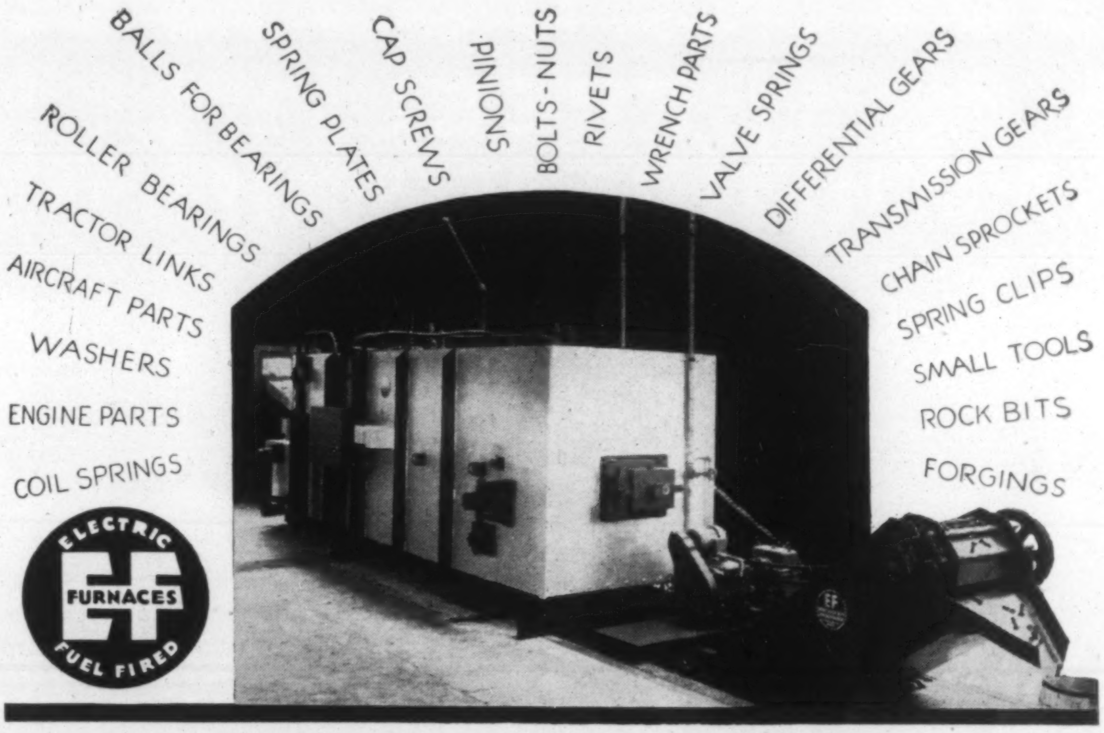
Personals

Tracy C. Jarrett, formerly assistant metallurgist with the American Optical Co., has been appointed chief metallurgist for Koppers Co., American Hammered Piston Ring Div., Baltimore, Md. . . . *Chas. H. Hoefer* has been made general superintendent of Duraloy Co., Scottsdale, Pa. . . . *J. A. Buell,* chief engineer, and *Myles Morgan,* assistant chief engineer of Morgan Construction Co., Worcester, Mass., have become vice presidents of that company.

G. C. McCormick and *W. R. Blair,* formerly of General Alloys Co., are now president and vice president respectively of a new company, Sterling Alloys, Inc., Woburn, Mass. . . . *Ray P. Farrington* has resigned as vice president of Alloys Plating Laboratories, Pittsburgh, to become chief inspector of the Philadelphia Ordnance District, Army Ordnance Dept.

C. E. Swift now directs the development, production and distribution of Ampco-Trode welding rods for Ampco Metal, Inc., Milwaukee, Wis. . . . *Raymond E. Christie,* previously assistant to the president, was recently elected vice president and director of Crucible Steel Co. of America at New York.

Howard A. Smith, erstwhile Duraloy Co. metallurgist, is now research metallurgist with Universal Cyclops Steel Corp., Bridgeville, Pa. . . . Carpenter Steel Co. has announced the promotion of *E. J. Poole, Jr.* to be vice president in charge of manufacture, and of *Frank R. Palmer* to be vice president in charge of sales.



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. . . Investigate E F Chain Belt Conveyor Furnaces

Hundreds of these dependable E. F. Continuous Chain Belt Conveyor Heat Treating units are in operation—handling all kinds of products, ranging in size from small springs and bearing parts up to large crawler links for tractors.

The material is loaded directly onto a rugged heat resisting cast link belt conveyor. Without further attention, it is carried through the furnace, uniformly heated to the proper temperature and automatically discharged through a sealed chute to the quenching medium or directly from the furnace as desired. The chain belt conveyor returns within the furnace without cooling . . . no pans or trays are used in the furnace . . . 100% net material.

These furnaces are built for oil, gas or electric heat in 5 standard sizes with capacities ranging from 300 to 1700 lbs. per hour. Larger or smaller sizes can also be furnished. They are also designed for using special protective atmospheres for scale-free heat treating and hardening without decarburization.

The hundreds of installations in operation handling all kinds of material, have proven them the most satisfactory and dependable general purpose heat treating machines built for the uniform, economical, production heat treatment of miscellaneous small and medium sized parts and products.

We will be glad to give you complete information, including installation and operating costs and submit heat treated samples if interested.

The Chain Belt Conveyor Furnace is only one of the numerous types we build for various heat treating purposes. We build Gas Fired, Oil Fired and Electric Furnaces in various types . . . furnaces for any process, product or production.

We solicit your inquiries.

The Electric Furnace Co., Salem, Ohio

Gas Fired, Oil Fired and Electric Furnaces---For Any Process, Product or Production

● *George Scherr Co., Inc.,* 125 Lafayette St., New York, is now exclusive sales distributor for the Wilder micro-projector. The latter is an accurate machine for measuring or comparing objects by means of a magnified shadow image and is used in inspecting gears, screw threads, punchings, etc.

Thermocouple Checking Furnace

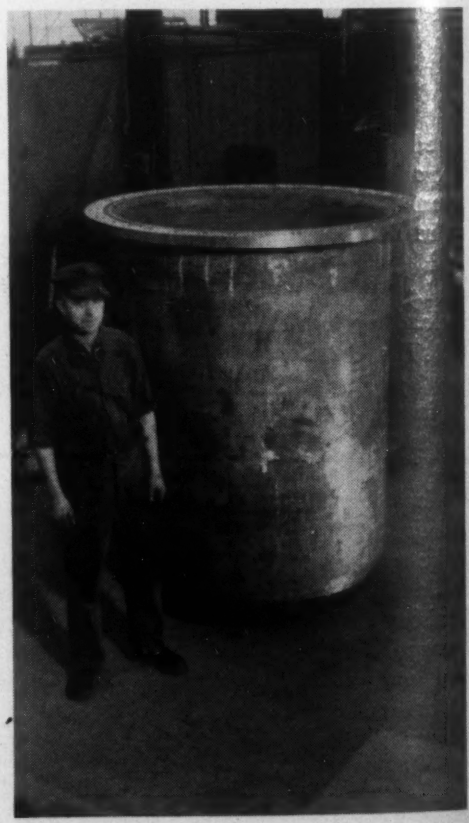
Greater checking accuracy and wider temperature range are features of the newly designed thermocouple checking furnace of *Leeds & Northrup Co.,* 4934 Stenton Ave., Philadelphia. The unit is a small electric furnace that provides a zone of practically uniform temperature for the intercomparison of laboratory standard couples and for comparison of laboratory standard and plant standard couples.

A new accessory that increases accuracy is a cylindrical copper equalizing block that fits inside the furnace; into the block are drilled 5 wells to hold the standard couple and 4 couples being checked. The block permits ±1 deg. F. checks from 70-100 deg. F., whereas without it checks can be made within ±3 deg. F. from 300 to 1800 deg. F.

The furnace is available with heating elements for either a.c. or d.c. on 115 or 230 volts, the input ranging from 40 watts at 300 deg. F. up to 1000 watts at 1800 deg. F. Working space inside is 4 in. in diameter and 36 in. deep.

Large Autoclave Casting

An autoclave of 350 gallon capacity, produced from acid and corrosion resistant metal, was recently cast for an Eastern chemical company by *Ampco Metal, Inc.,* Milwaukee. The metal used for this large casting was Ampcoloy E-1, an aluminum bronze of controlled analysis.



The autoclave has an overall height of 5 ft. 3 in., while its diameter at the top, with flange, is 4 ft. 10½ in. The body itself has an inside diameter of 3 ft. 8 in., and the walls are 1¼ in. thick. The total weight of the casting was 5,014 lbs.

FREE!
A SCIENTIFIC PRESCRIPTION
for
Soldering Practice in Your Production

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*Kx
1 of 100 different solder-alloys
1 of 10 different solder-fluxes
1 of 80 different solder strand-sizes
1 of 4 different solder core sizes
"COMPOUNDED BY KESTER"

Here's a service that may be of vital importance in many operations in your production.

In this day of alloys, the solder problem is complicated. For best results, solder must be exactly adapted to the work at hand. This means that the right solder-alloy and flux must be used in the right strand and core-size.

At Kester you have available 100 different solder-alloys and 10 different solder-fluxes, 80 different solder strand-sizes and 4 different solder core-sizes. The big thing is to get the *right* combination of these four elements for each of the metals involved in your production.

Here's the way to get this important information. Just mail a description of your soldering operations to the address below. Your Kester Solder-Prescription will come forward to you promptly.

You place yourself under no obligation by making use of this free scientific soldering service.

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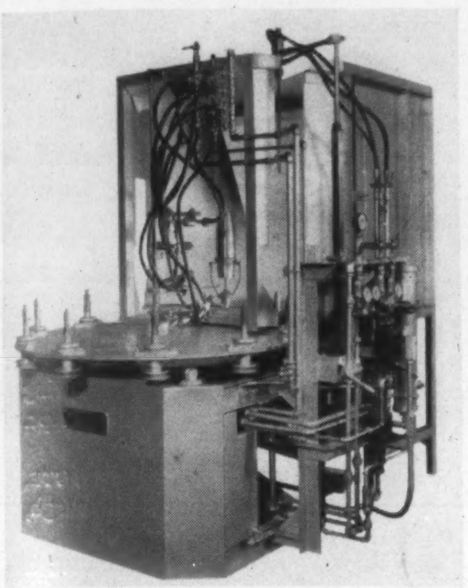
KESTER SOLDER COMPANY
4219 Wrightwood Avenue, Chicago, Illinois
Eastern Plant: Newark, N. J. • Canadian Plant: Brantford, Ont.

KESTER CORED SOLDERS
STANDARD FOR INDUSTRY

Shell Coating Machine

A machine that automatically coats both the inside and outside of shells is now available to manufacturers from the *DeVilbiss Co.,* Toledo. The new machine is capable of coating shells from 37 mm. to 105 mm.

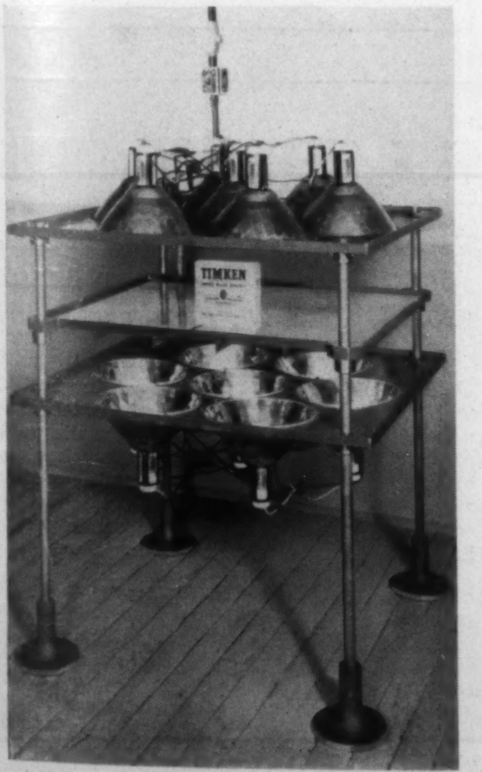


Operation is entirely-automatic, except for loading and unloading shells on the holding spindles. Synchronization is such that while the interior of one shell is being coated the exterior of the preceding shell is being sprayed. The machines can coat 300-400 shells with all spindles continually loaded.

In addition to shells, the DeVilbiss machines are used to coat tail pieces and fragmentary-bomb sub-assemblies. Production on the former is up to 2400 per hr.; on the latter, up to 300 an hr.

Infra-Red Heating of Bearing Cones

A novel method in use for heating bearing cones prior to assembling them on shafts, where a tight press fit is required, involves the use of infra-red rays, according to *Timken Roller Bearing Co.,* Canton, O.



Three trays about 4 ft. square are set up with about 12 in. vertical space between them; the middle tray, of Pyrex glass, contains the bearing cones *stacked in their containers,* while the top and bottom trays each carry seven 250-watt infra-red bulbs in gold-plated reflectors. About 20 min. is required to heat a bearing to 155 deg. F., during which time the cardboard containers remain relatively cool.

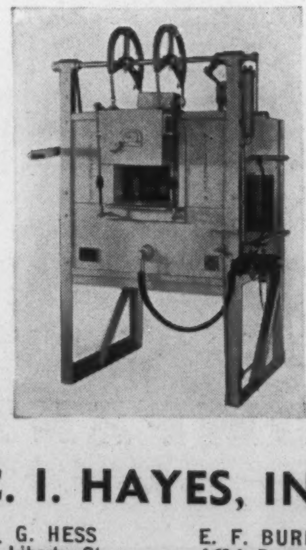
When this method of heating is used, it is not necessary to wash off the protective coating that is put on the bearings at the time of packing.

- The *Anglo-American Metal & Ferro-Alloy Corp.* plans to engage in the manufacture of nickel alloys and allied products in addition to its present field of activity. The new nickel alloy business will be under the name of *American Nickel Alloy Mfg. Corp.,* and both companies will maintain new offices at 50 Church St., New York.

- *Carl Zeiss, Inc.,* 485 Fifth Ave., New York, states that its plant is now manufacturing the Zeiss Micro-Hardness tester, said to permit accurate hardness testing of microscopic areas on metal surfaces.

Certainty!

Bringing Heat-treating Certainty to hundreds of defense projects



In naval, army ordnance, and aircraft work, as well as in hundreds of plants tied in with the defense program, "Certain Curtain" furnaces are increasing production, forestalling spoilage, and improving working life of tools and dies. The patented Hayes control of furnace atmosphere permits the most difficult steels and the most delicate tools to be heat-treated at an "all-out" pace with bullseye certainty. With our doubled capacity, we are scheduling new orders for reasonable 1941 delivery.

SINCE 1928-WORLD'S LEADING
★ ELECTRIC CERTAIN CURTAIN FURNACES ★
CONTROLLED-ATMOSPHERE FURNACE

C. I. HAYES, INC., EST. 1905, PROVIDENCE, R. I.

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92 Liberty St.	4614 Prospect	6388 Penn Ave.	202 Forest Ave.	4939 N. Talman
New York	Cleveland	Pittsburgh	Royal Oak, Mich.	Ave., Chicago

Dust and Fume Collectors

A new line of unit dust collectors in 2,000 to 10,000 c.f.m. capacities is announced by *Claude B. Schneible Co.,* 3951 Lawrence Ave., Chicago, and should interest many metallurgical engineers concerned with foundry operations, pack-hardening, blast cleaning, spray finishing, etc.

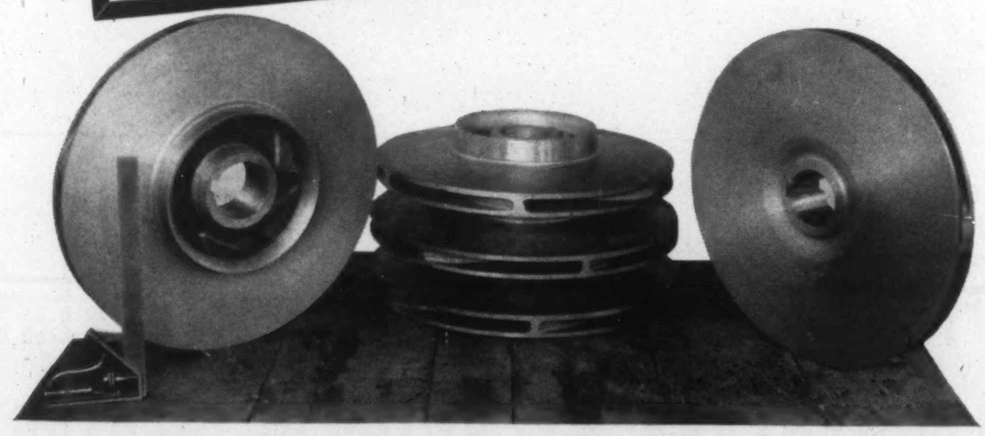
The new models, designated type "UC," consist of a fan, 5-spray curtain tower, pump, settling chamber and sludge ejector-conveyor. The collector tower is of the Multi-Wash design. It is claimed that heavy particles are precipitated in the lower inlet cone of the collector, fines being collected and washed back into the sludge chamber by the downward-moving water-spray curtain.

● *The Summerill Tubing Co.,* Bridgeport, Pa., is establishing a series of prizes, to be awarded by the *American Welding Society,* 33 W. 39th St., New York, at its October 1941 meeting, for papers to advance the art of welding of aircraft steels, including tubing and steel parts for tubular assemblies. Information on the prizes, which total $600, may be obtained from the Society.

● *Carboloy Co., Inc.,* Detroit, announces the addition of 5 new styles to its low-price mass production line of standard tungsten carbide tools. Available in 21 sizes, the new tools are all carried in stock and comprise 4 off-set types and a 2-way square-shank turning style—almost all available in both a steel-cutting grade and an ordinary grade.

DURALOY

produces Chrome-Iron and Chrome-Nickel castings in the light of 19 years' experience and with the latest type of equipment.



Isn't that the kind of a casting you want—one backed by plenty of experience?

You will be assured (1) of the proper alloying elements for the conditions to be met; (2) of a sound casting throughout.

Duraloy has the plant, equipment and experience to turn out just about any kind of a high alloy casting, with chromium nickel, molybdenum, and others as the alloying elements to meet conditions of corrosion, high temperatures, and abrasion. Write for our general catalogue.

DURASPUN CENTRIFUGAL CASTINGS

Since 1931 we have been making high alloy centrifugal castings on a commercial basis. That makes us also experienced in this phase of the alloy casting business. You should investigate these castings for all your requirements. If they fit into the picture at all they would be superior to anything else you could get. The metal is stronger and denser than that in static castings.

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Detroit
The Duraloy Co. of Detroit

Scranton, Pa.
Coffin & Smith

St. Louis
Metal Goods Corporation

Los Angeles
Great Western Steel Company

Meetings and Expositions

ELECTROCHEMICAL SOCIETY, spring meeting. Cleveland, Ohio. Apr. 16-19, 1941.

AMERICAN PETROLEUM INSTITUTE, division of production. Pittsburgh, Pa. Apr. 17-18, 1941.

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, national open hearth steel conference and blast furnace and raw materials committee meeting. Chicago, Ill. Apr. 23-25, 1941.

NATIONAL METAL TRADES ASSOCIATION. Chicago, Ill. May 8-9, 1941.

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION. Hot Springs, Va. May 12, 1941.

AMERICAN FOUNDRYMEN'S ASSOCIATION, annual meeting. New York, N. Y. May 12-15, 1941.

AMERICAN SOCIETY FOR METALS, Western Metal Congress and Western Metal Exposition. Los Angeles, Calif. May 19-23, 1941.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, semi-annual meeting. Chicago, Ill. May 19-21, 1941.

AMERICAN PETROLEUM INSTITUTE, mid-year meeting. Fort Worth, Texas. May 19-23, 1941.

AMERICAN IRON & STEEL INSTITUTE, general meeting. New York, N. Y. May 22, 1941.

FREE SERVICE DEPARTMENT

Replies to box numbers should be addressed care of METALS AND ALLOYS, *330 W. 42nd St., New York.*

POSITION WANTED: Metallurgist, 39, Ph.D., 12 years non-ferrous metals laboratory and plant experience including metallography, physical testing, heat treatment of aluminum, magnesium, red and white metals, coatings, successful research worker, 4 years in this country, employed, desires responsible position in plant or research laboratory. Box MA-5.

POSITION WANTED: Metallurgist, 5 years' experience in development research in non-ferrous and ferrous metallurgy, B.S. and Ph.D. in metallurgical engineering, also 5 years' experience in chemical analysis previous to college work. Prefer development research in non-ferrous process metallurgy. Married and American citizen. Box MA-6.

METALLURGICAL ENGINEERING shop notes

Fast Repair of a Special Tap

by F. T. Van Syckel
Handy & Harman

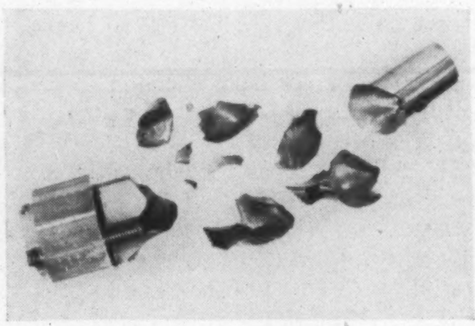
In a large mid-west plant a special 1⅜ in. high speed steel tap was shattered in service. It broke in 10 pieces of various sizes and shapes (see top photo) and threatened to tie up production on an important job.

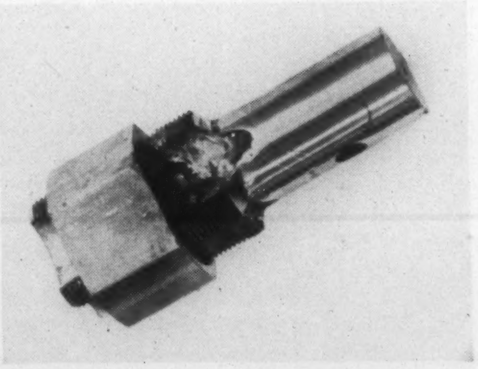
A check-up with tool manufacturers brought the advice that a new one could not be delivered for 6 weeks, so the tool maintenance department decided to attempt a repair. The head of this department, familiar with high speed steels, knew that welding was practically impossible but believed that brazing with low-temperature silver brazing alloys might solve his problem.

Accordingly, he had all parts cleaned carefully and fluxed with a low-temperature flux. The broken parts were then assembled and held close together in a milling machine vice. Heating was done with an oxyacetylene torch; a medium-silver brazing alloy ("Easy-Flo") flowing freely at 1175 deg. F. was used. The exceptional penetrating qualities of this alloy aided it in flowing throughout the many surfaces that had to be joined. The tap as it looked after this repair-by-brazing was accomplished is shown in the lower picture.

How well this repair was completed can be judged by the fact that the tap was back in service in 4 hrs. That was last October, and a report dated January 11, 1941, states that the tap is still in use. The actual brazing time for the job was but ½ hr. and only 3 in. of 1/16 in. diameter silver brazing alloy wire was used to make the repair.

The only fault detected after brazing was that the tap was 0.005 in. out of center, which happened to make no great difference on the particular work being done. The job did prove conclusively, however, that a braze of this type gives plenty of strength to withstand severe service conditions.





Porosity in Aluminum Castings

Pinholes and gasholes when found in "Y" alloy and other aluminum alloy castings are normally due to shrinkage, and shrinkage may be caused by a number of things—pouring the metal too hot, overheating the metal during melting so that it is "burned" or oxidized, or the use of inadequate heads and risers on the casting to feed the large amount of shrinkage during cooling.

Therefore, caution should be used so that the metal is not overheated during melting, that it be poured into the mold as cool as possible without producing cold shots in the finished casting, and that gates and risers be of ample size to feed the casting until after it has set.

Porosity of this type may also be reduced in casting by judicious placing of chills in the mold to accelerate freezing; the more rapidly the casting is chilled after pouring, the more efficient will be the feeding action of the risers.

The addition of titanium to the aluminum alloy will decrease subsurface pinholes and porosity and improve the surfaces to be machined and polished, and will also give a finer-grained casting. The recommended addition is 2½ to 3 lbs. of aluminum-titanium addition alloy to each 100 lbs. of molten aluminum alloy treated, or enough to add 0.1 to 0.2 per cent titanium. The alloy should be thoroughly stirred before pouring as the titanium tends to settle to the bottom of the pot.

—from publications of
Niagara Falls Smelting & Refining
Corp. and of Titanium Alloy Mfg. Co.

Removal of burrs from machined parts, ordinarily carried out by tedious hand grinding, filing or scraping, can be rapidly and efficiently done on many parts by blasting with a fine metallic grit in an airless blast cleaning machine, such as the Wheelabrator Tumblast. A few minutes' blasting is all that is usually required. In addition, the blast treatment not only removes the burrs, but provides an excellent bond for any subsequently applied surface coatings.

—American Foundry Equipment Corp.

Inconel wire fixtures or holders are useful for dipping gears to be case hardened in molten salt baths, since they retain their strength very well in the bath and resist scaling when exposed to the air while hot.

—Inco, International Nickel Co., Inc.

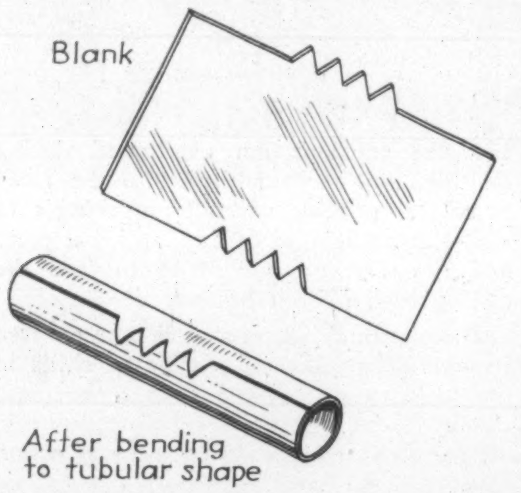
(MORE SHOP NOTES ON PAGE 462)

Serrated Rivets for Aircraft

by R. Cox
General Aircraft Ltd.

An interesting design kink, evolved [in England] primarily to relieve pressure on the supply of drawn duralumin tubular rivets, offers promise of establishing itself permanently on an economy basis, and for other rivet materials as well as duralumin.

The technique comprises making tubular rivets from serrated sheet material, which is easier to obtain and less costly, even in normal times, than drawn rivets. The blank, with its interlocking serrations, is shown in the illustration. This is bent around its longer center-line to bring the serrations closer together and then in a second bending operation the tubular form is completed, with the serrations locked together. Finally, the head is formed.



The result is a rivet in which it is easier to form the head, since the metal is stretched much less than with the tubular rivet, because of the split at the joint line. For the same reason, any liability to fracture during heading is completely removed. The serrations themselves act as a key and provide torsional stability.

A diameter-to-thickness ratio of 5.5 is the lowest value that can be used and still avoid difficulty in forming. In our case it has been convenient to keep the form of the serration constant throughout the range of rivet diameters. Rivet lengths are standardized in 0.05 in. increments, and the number of serrations varies from 1 in. lengths under 0.7 in. to 6 in. lengths over 3½ in.

This type of rivet has a shear strength almost as high as that of conventional tubular rivets, and can thus be used as a direct replacement for drawn tubular rivets in existing design.

—*Engineering Inspection*
January, 1941

Vibration in automatic control-instrument panels, with consequent distortion in readings, can be eliminated by mounting the panel on special insulators (called "Vibro-Insulators"), which are combinations of rubber and metal in which vibration is absorbed by rubber held in shear. Booths in which panels are housed can also be insulated from the floor in the same way.

—*B. F. Goodrich Co.*

Recently we came upon an apt characterization of the readers of this magazine as "engineers skilled in the art of metallurgy". Skill in any art implies an intimate knowledge of its "know-how", and this department is designed to add its monthly bit to this store of practical information. You can do your bit, and also earn a little pin-money, by sending in original contributions for publication here.—The Editors.

Heat Treatment of S.A.E. 3312

by H. C. Griggs
Waterbury Farrel Foundry & Machine Co.

For the past 7 yrs. we have made gears, heavy-duty cams, etc. for our machines from S.A.E. 3312 steel (more accurately from the so-called "Krupp analysis"—3.75-4% Ni, 1.5-1.75 Cr). We do not normalize after rough machining, but have evolved instead a technique that gives us an as-quenched case hardness never lower than 60 Rockwell "C," with a minimum of distortion.

After forging, the steel is heated to 1550 deg. F. and cooled moderately fast in still air. It is then annealed at 1440 deg. F. and allowed to cool at a rate of 40-50 deg. F. per hr. until it reaches 600 deg. F. or below. This gives a constant and very low hardness of 170-180 Brinell, and machining is no more difficult than with the relatively easy-machining S.A.E. 4620 steel.

For carburizing, the steel is heated at 1650 deg. F. for 12-20 hrs. and oil-quenched directly from the box on its removal from the furnace. The carburized-and-quenched parts are then spheroidized at 1200 deg. F. and cooled in still air. For final hardening, the parts are reheated to 1420-1440 deg. F., cooled with the furnace to 1350 deg. F., and quenched in oil; draw temperature is between 350 and 500 deg. F., depending on the final hardness desired.

Distortion is remarkably small. On large cams of 24 in. diameter with holes ranging from 3 to 6 in. where they are forced on the shaft, there is a slight shrinkage—never over 0.005 in. We have never had an as-quenched case hardness less than 60 Rockwell "C" in any section that we have encountered, and have never had a failure of an S.A.E. 3312 part treated by this cycle.

—*Nickel Steel Topics*
International Nickel Co., Inc.

The solution treatment of magnesium alloy castings can be effected without employing a controlled atmosphere by dipping the sand-blasted castings for a few seconds in a 10 per cent solution of hydrofluoric acid before inserting them in a furnace having the normal muffle atmosphere. The "dip" produces a perfect sealing coat of magnesium fluoride, and the heat treating practice may otherwise be identical with that used in a controlled atmosphere.

—A. T. Steer
in Metal Treatment

Machining Metal-Sprayed Surfaces

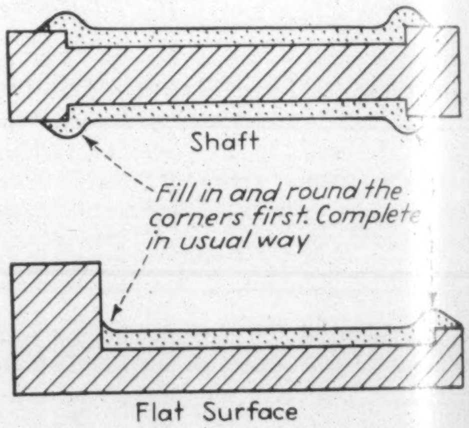
by R. A. Axline
Metallizing Engineering Co., Inc.

Most metallized surfaces machine quite easily, provided certain fundamental rules are observed, although others, such as hard stainless steel coatings or high carbon steels, must be finished by grinding. The greatest single factor in the machinability of sprayed metal is the particular wire used, and it is therefore generally advisable to employ only wires manufactured specifically for metal-spraying.

A check list of the important factors that affect the machinability of sprayed metals would include:

1. Analysis and drawing specifications or the metallizing wire.
2. Texture of the coating (or the fineness of atomization).
3. Cleanliness and freedom-from-oil of the air supply.
4. Distance between gun-nozzle and work.
5. Angle at which the sprayed metal strikes the work. The smaller this angle, the more difficult the metal will be to machine; 90° is best, and 45° an absolute minimum.
6. Traverse speed when spraying.
7. Flame setting on the gun.
8. Spraying into undercuts and corners.
9. Subsequent treatment of sprayed surface.

One trouble often encountered is the hard ring that forms next to the ends of the undercut section when spraying carbon steels on shafts, in corners, etc. The condition may be minimized by concentrating the spray into the corners when starting the job, so as to partially fill and round them out—as shown in the illustration. While working on the corners, frequent quick passes should be made over the remainder of the surface so that the bond will not be impaired by dust collecting in the pores.



When machining, it is advisable to finish these hard sections first, with a blunt-nosed tool, before inserting the tool that will be used for the rest of the sprayed section. The use of a lubricant consisting of 1 part cylinder-oil plus 1 part kerosene is helpful in machining any hard spots encountered.

An effective system for cleaning brass, copper and zinc alloys prior to electroplating comprises (1) pre-cleaning with an emulsifying solvent or an alkaline compound, depending on the work, (2) anodic cleaning with an alkaline electrocleaner compounded specifically for this purpose, and (3) sulphuric acid dip. Rinsing, of course, follows each operation.

—*Oakite News Service*
Oakite Products, Inc.

Metallurgical Engineering Digest

FERROUS AND NON-FERROUS

A Digest of Important Developments in the World of Metals

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1. Production

Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining. Open-Hearth, Bessemer, Electric-Furnace Melting Practice and Equipment. Melting and Manufacture of Non-Ferrous Metals and Alloys. Soaking Pits and other Steel-Mill and Non-Ferrous-Mill Heating Furnaces. Steel and Non-Ferrous Rolling, Wire Mill and Heavy Forging Practice. Foundry Practice, Furnaces, Equipment and Materials. Manufacture of Die-Castings.

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4. Testing and Control

Physical and Mechanical Property Testing and Inspection. Routine Control and Instrumentation. X-ray and Magnetic Inspection. Spectrographic and Photoelastic Analysis. Corrosion- and Wear-Testing. Examination of Coatings. Surface Measurements. Metallographic Structure and Constitution.

5. General

Articles pertinent to more than one of the previous sections.

1

Production

OF METALS, MILL PRODUCTS, CASTINGS

Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining. Open-Hearth, Bessemer, Electric-Furnace Melting Practice and Equipment. Melting and Manufacture of Non-Ferrous Metals and Alloys. Soaking Pits and other Steel-Mill and Non-Ferrous-Mill Heating Furnaces. Steel and Non-Ferrous Rolling, Wire Mill and Heavy Forging Practice. Foundry Practice, Furnaces, Equipment and Materials. Manufacture of Die Castings.

Clay Binders for Molding Sand

The Importance of the Swelling Capacity of Clay-type Binders for Molding Sand ("Ueber die Bedeutung der Quellfähigkeit toniger Bindemittel für Giessereisande") K. Endell, H. Reininger, H. Jensch, P. Csaki. *Giesserei*, Vol. 27, Nov. 29, 1940, pp. 465-475; Dec. 13, 1940, pp. 499-502. Practical review plus research.

The properties of clays and their suitability for foundry sands are surveyed, and some practical correlations are made between the capacity for swelling of clay binders in water and their use in preparing good molding sands. In both natural and synthetic foundry sands with clayey constituents, the clay is the binder and the quartz material the filler; the binder determines, besides the grain structure of the filler mass, all the technological properties of a molding sand.

The investigation showed that bentonites are far superior to kaolin clays with regard to binding capacity and strength in the green and dried states. A comparison between sands made with American sodium-bentonite and German sodium-bentonite showed that in all cases the mechanical strength in the green state was considerably higher with the German bentonite (for the same concentrations) while the strength in the dry state is higher with the American bentonite. Bentonites give good values of mechanical strength even in low concentrations—concentrations at which highly plastic kaolin clays would not bind at all. Furthermore, the strengths in both the green and dry states are as great for high bentonite concentrations as for the same kaolin concentration.

The highest mechanical strengths are obtained with the sodium-bentonites. With respect to suitability for foundry use, no fundamental difference exists between natural and synthetic molding sand. However, only with synthetic sand is it possible to obtain definite extreme values for gas permeability, shearing and compressive strength in green state, dry strength and water content and to maintain controllable uniformity; also, undesirable contaminants such as iron oxide, lime, etc., can be avoided in synthetic sands, giving castings that are easier to clean. Synthetic sands can also be re-used more often.

The high dry strength of cores of sodium-bentonite and pure quartz sand is of particular value for the casting of magnesium alloys, where contact between melt and gases must be avoided as much as possible. Kaolin clays are absolutely unsuitable for making synthetic sands.

In attempting to evaluate a binder for molding sands, the following factors must be determined: (1) the mineral content in the binder by chemical, petrographic and X-ray analysis, (2) particle size of the minerals by dispersoid-analytical methods, (3) the total sorption capacity and the cations, and (4) the swelling behavior in the Enslin apparatus. Ha (1)

1a. Ferrous

Edge Cracks in Hot Rolling

Formation of "Pressure-Folding" Cracks in the Free-to-Spread Rolling of Steel, With an Appendix: Phenomena on the Surface of a High-Chromium Stainless Cutlery Steel ("Entstehung von Druckfaltungsrissen beim freibreitenden Walzen von Stahl, mit einem Anhang: Erscheinungen an der Oberfläche eines rostfreien Messerstahles mit hohen Chromgehalt") A. Pomp & W. Lueg. *Mitt. Kaiser-Wilhelm-Inst. Eisenforsch. Düsseldorf*, Vol. 22, No. 16, 1940, pp. 241-254. Investigation.

"Pressure-folding" cracks are the surface defects and cracks that occur because of roughness originating at the sides of the hot-rolled material if spreading is not hindered during rolling. If the roughened areas are exposed in the course of subsequent deformation processes to an unfavorable upsetting effect, cracks are formed; these can even become large enough to cause the material to be rejected. This type of roughing can also occur in the rolling of profiles.

The steels studied were of the following types: (1) plain carbon steel, with 0.88% C; (2) chromium-moly steel with 0.37 C, 1.05 Cr and 0.17 Mo; (3) nickel carburizing steel, with 0.13% C and 3.74 Ni; and (4) stainless cutlery steel with 0.41% C, 13.6 Cr. The steels were rolled in 4 passes in a temperature range of 1300°-2200° F. and their surfaces tested by the magnetic powder method and by hot etching.

All steels showed an increased roughness of the surface with increasing temperature of rolling; the carbon steel had the smoothest surface, then came the chromium-molybdenum steel, then the nickel steel. The cutlery steel had a smooth surface, but when rolled at 1800°-2000° F. developed many longitudinal cracks.

When this last steel was deep-etched numerous "pickling cracks" occurred, which were attributed to shearing stresses produced by the flow of the material in the direction of spreading. The nickel steel has the greatest tendency to form pressure folds while the stainless cutlery steel was extremely sensitive to a non-uniform distribution of the flow of the material over the section. The occurrence of pickling cracks in the cutlery steel could be prevented by cooling the rods or slabs in the furnace after rolling, or coating them, before rolling, with saturated borax solution.

The appendix treats in more detail of the occurrence of surface defects, especially "pickling cracks," in the cutlery steel, and describes the method of deep-etching which caused these cracks. The cracks were definitely not caused by too-long etching, since they formed even after etching periods of 5 min. Photographs show the surface with and without protective treatment in furnace and with borax. Ha (1a)

Desulphurizing Pig Iron in Europe

"Recent European Developments in Pig Iron Manufacture." N. L. Evans. *Foundry Trade J.*, Vol. 64, Jan. 9, 1941, pp. 19-22. Review.

Difficulties in blast furnace practice encountered in England in the early 1930's, when the low-grade aluminous iron ore deposits of Northamptonshire were being developed for basic steelmaking, were overcome by modifying the burden so that the slags formed were of low melting point (Brassert's process at Corby, Paschke & Peetz' method, etc.). Slags of high lime together with high-alumina content have high melting points, with consequent difficulties of operation.

Slags of low melting points may have a lower capacity for carrying sulphur than do the high-lime slags of common practice, and in the manufacture of basic pig iron it is desirable that the liquid iron be desulphurized after tapping the metal from the blast furnace. Such desulphurization may be obtained by the use of limey slag, by manganese additions and by treatment with sodium carbonate in a ladle. The last method is capable of application to a very wide range of pig irons. In 1938-1939, sodium carbonate was being used for metal refining in Germany, France, Belgium and Luxembourg at the rate of 80,000-100,000 tons of carbonate/yr.

The first major continental development employing sodium carbonate treatment was the "O.M." (*ohne mangan* or manganese-free) process. In a series of experiments carried out in Luxembourg, the addition of manganese ore to the blast-furnace burden was progressively lowered. The furnace, which was making basic iron, was operated with a slag having a basicity ratio CaO : SiO_2 = 1.45 : 1. The iron was desulphurized in the ladle by treatment with sodium carbonate, the consumption of sodium carbonate being about 11 lbs./ton of iron. With this practice the average decrease in the sulphur content of the metal was 38%, *i.e.*, from 0.08% S to less than 0.05% S, a further reduction taking place in the basic converter.

At the end of the dephosphorization stage in the converter, the residual manganese in the iron was 0.08%, as compared with 0.20% when the blast furnace

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was operated with manganese additions. The usual manganese additions were made to the steel after blowing. Steel made by this process, of an extra soft quality, was found to give very good results in processing and fabricating operations. The "O.M." method of operation also effected a considerable reduction in costs.

It has been demonstrated that sodium carbonate treatment of the basic Bessemer grade of pig iron improves its fluidity. The gauge used for measuring fluidity consists of a cast iron mold in two parts screwed together, comprising a U tube of 10 mm. diam. with a tun-dish on the top of one limb. A third limb, 4 mm. in diam., is graduated in millimetres along its length. The molten metal under test is poured into the tun-dish until it reaches the top of the other 10-mm. limb. The distance of the flow along the 4-mm. limb before solidification is a measure of the fluidity of the metal.

At Völklingen the Germans were operating an acid-burden process and desulphurizing with *molten* sodium carbonate. Beneficiation of the low-grade German ores is, of course, essential to their smelting in an acid-burden process. The sodium carbonate was separately melted, tapped into an unlined, preheated ladle, and poured through a tun-dish into the stream of iron in the blast-furnace runner and thence into the hot-metal ladle (lined with firebrick containing 32% alumina). The iron, during transfer from the hot-metal ladle to the mixer, is poured through a deep layer of sodium-carbonate slag in a tea-pot ladle, lined with a mixture of tar and dolomite.

By using molten sodium carbonate up to 1% of the weight of metal, the sulphur was reduced to 0.04% from 0.12%. 1.2% sodium carbonate reduced the sulphur content from 0.18 to 0.06% S. Molten sodium carbonate has been claimed to be a 20-25% more effective desulphurizer than the solid form.

In Germany the waste soda slag is crushed and mixed with phosphate rock, and the mixture is melted, granulated, ground and used as a fertilizer. The highly siliceous acid blast furnace slags from German acid-burden processes are utilized for cement manufacture and brick making.

In Great Britain the use of sodium carbonate as a desulphurizer has been long established, but its application to other than basic iron has been limited by the infrequent use of hot-metal ladles. There is now, however, a growing tendency to use hot-metal ladles and pig-casting machines, which, because they provide uniform mixing and freedom from sand inclusions, mean uniform pig iron for the foundryman and a step toward the abandonment of outmoded "rule-of-thumb" foundry practices. AIK (1a)

Defects in Open-Hearth Ingots

ELIMINATING DEFECTS IN LARGE INGOTS OF BASIC OPEN-HEARTH STEEL ("Die Verminderung von Fehlern in grösseren Blöcken aus basis-chem Siemens-Martin-Stahl") E. WULFFERT. *Stahl u. Eisen,* Vol. 60, Sept. 19, 1940, pp. 833-838. Practical.

A statistical study was made of the effect of (a) type of finishing slag, (b) rate of carbon drop, and (c) pouring temperature on coarse dendritic structure and porosity in large ingots of forging steel. Non-metallic inclusions were not considered.

Unduly coarse dendritic structure and porosity along the longitudinal axis of the ingot were at a minimum when the iron content of the slag was between 8 and 10%, when the rate of carbon drop was no more than 0.27% C/hr., and when the pouring temperature was between 2860° and 2900° F. The rate of carbon drop depended considerably on the heat input to the furnace which could be adjusted by proper fuel control. Porosity was found to accompany a coarse type of dendritic structure.

Under the solidification conditions obtaining with the pouring temperatures given above, such coarse dendritic structure and porosity could be almost entirely eliminated. In discussion Guthmann gave a summary of recent pouring temperature measurements by optical and thermocouple pyrometers, in Germany and the U. S., indicating favorable pouring temperatures for steels of different carbon contents. SE (1a)

Dried Air for Bessemers

TECHNICAL AND ECONOMIC FACTORS IN AIR DRYING IN BASIC BESSEMERS ("Technische Bedeutung und Wirtschaftlichkeit der Windtrocknung im Thomasstahlwerk") W. EILENDER & P. VEIT. *Stahl u. Eisen,* Vol. 60, Oct. 10, 1940, pp. 905-910. Practical.

On a hot humid day, 300 lbs. of water may pass through the charge of a 20-ton Bessemer converter as moisture in the air-blast. Assuming 80% dissociation of the moisture in the converter, this consumes 310,000 Kg.-cal., or enough heat to melt 1 ton of scrap, about 5% of the charge.

Also, part of the hydrogen formed when the moisture decomposes escapes with the converter gases, but a large proportion is absorbed by the molten metal. The solubility of hydrogen in molten iron at 2900° F. is 29 cm.^{3} of hydrogen per 100 gm. of iron. The object of drying the air was not only to save heat but to avoid injuring the steel. The hydrogen may be responsible for blowholes and voids in the solidifying steel and shatter cracks after the steel has solidified. In basic Bessemer steel the effect of moisture in the burnt lime used is negligible in comparison with the effect of moisture in the air blast.

Two methods were used to dry the air blast: (a) refrigeration, and (b) absorption with silica gel. The latter proved more economical. With a moisture content of the air of 8.3 gm./m^3, a heat saving (allowing larger scrap additions) of 8 Pfennig/ton of steel was effected. In addition, pig iron lower in phosphorus could be used, so that the overall saving of drying the air blast with silica gel was calculated to be 1.3 R.M./ton. SE (1a)

Inclusions in Iron

"THE METALLOGRAPHY OF INCLUSIONS IN CAST IRONS AND PIG IRONS." H. MORROGH. *J. Iron & Steel Inst.,* Advance Copy, May 1941 meeting, 47 pp. Research.

A scheme of classifications for inclusions in cast iron and pig iron was developed. Various experiments were made to determine the nature and mode of occurrence of the different inclusions. The effect of pouring temperature on the morphology of MnS is discussed.

Both manganese and iron sulphides were found to serve as nuclei for the formation of temper carbon in malleable iron. MnS tends to give temper carbon in the form of graphite-flake aggregate while FeS gives spherulitic temper carbon.

A blue-pink constituent was observed in iron containing titanium and insufficient manganese to combine with all of the sulphur. This constituent was prepared in a number of melts and shown to be probably titanium sulphide. The complicated optical properties of this inclusion as revealed by the polarizing microscope are described in detail.

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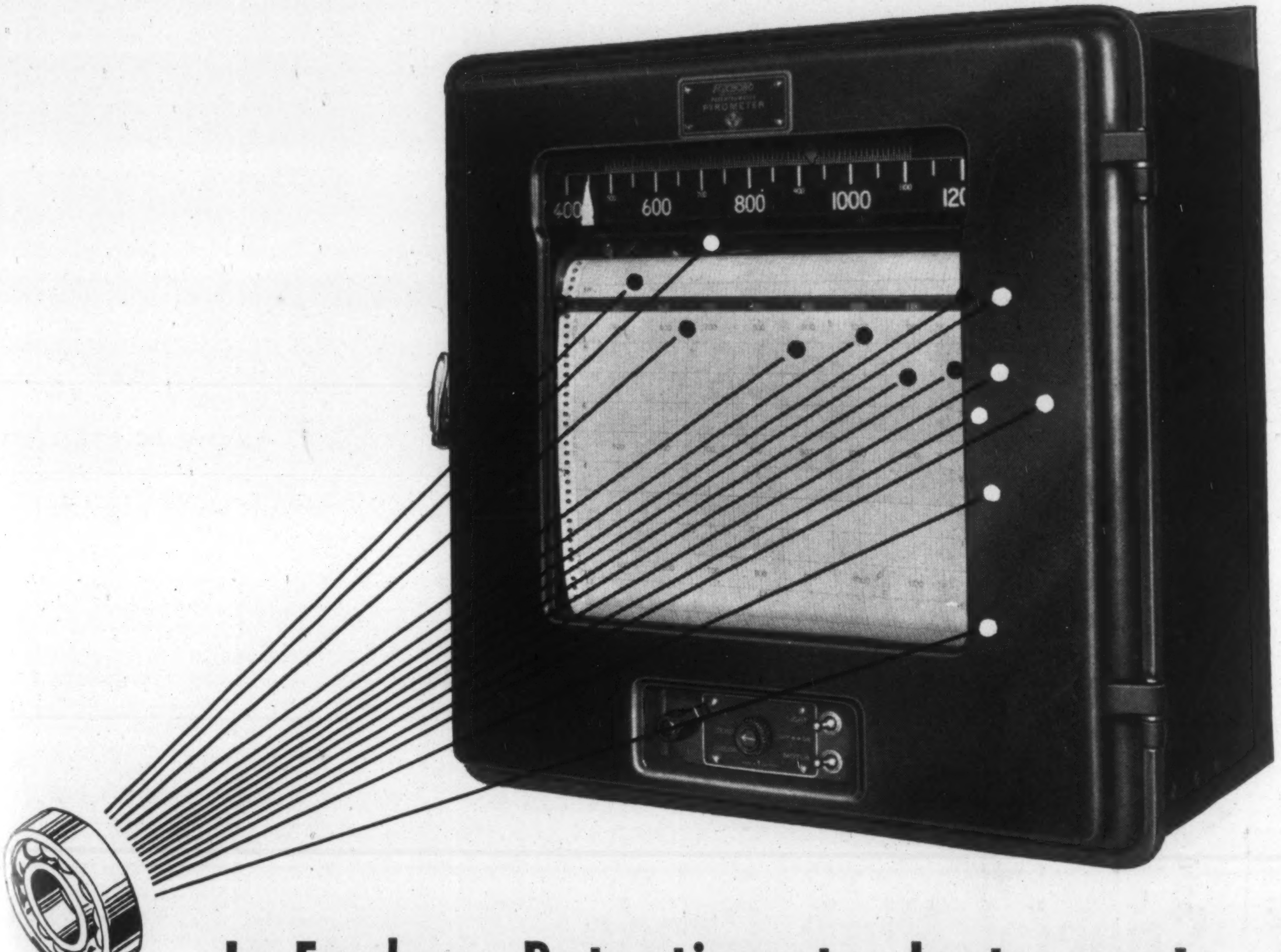

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to about 0.5%, on the inclusions in cast iron was studied. With increasing zirconium it was found that the MnS in the base iron was gradually replaced by an orange-yellow to gray inclusion. When all the MnS had been removed from the structure, blue-gray cubes of zirconium carbide appeared, which combined with the titanium carbide present to give a complex titanium-zirconium carbide. In melts made in a rocking-arc furnace, the yield of zirconium from iron-silicon-zirconium alloy was poor and most of the zirconium appeared to be fixed as lemon-yellow zirconium nitride. An attempt to introduce this inclusion into crucible-melted cast iron by bubbling nitrogen through the melt failed.

Very little analogy was found between the inclusions in steels and cast iron, the latter being characterized by the almost complete absence of visible oxides or silicates. It is suggested that the small particles referred to in the paper could be termed "minor phases" to great advantage with regard to definition. JLG (1a)

Rimming Steels

"Solidification of Rimming Steels." T. Grey Davies. *Sheet Metal Inds.*, Vol. 14, Nov. 1940, pp. 1174-1175, 1178. Practical.

Rimming steels generally contain 0.12% C maximum and 0.5% Mn maximum. Solidification is decisively affected by the evolution of gas, mainly carbon monoxide, resulting either from reaction or reduced solubility. The principal recent innovations in manufacture are: (1) special molds (their use is widespread in America) and (2) use of sodium fluoride.

Sodium fluoride additions have an effect opposite to that of aluminum, namely, they speed up the effervescence of the ingot. The standard procedure is to add 2 oz./ton during teeming. The effect is most marked in small ingots in which the height to cross-section ratio is over 4 to 1. Sodium fluoride addition at the start of pouring increases the rimming action in the lower half of the ingot, thereby giving an ingot with more uniform skin thickness and surface quality. Sodium fluoride is especially useful for heats that are somewhat sluggish in rimming and that might give second-grade ingots.

The reason for this action of sodium fluoride is not known; however, in view of the known action of calcium fluoride in increasing the fluidity of slags, it may increase the fluidity of the inclusions in the steel. Since rimmed steel generally has complex inclusions at the junction of rim and core, it may be that the increased fluidity of these inclusions permits the longer solidification of the pure rim.

JZB (1a)

1b. Non-Ferrous

Electrolytic Manganese

"Electrolytic Manganese and its Potential Metallurgical Uses." R. S. Dean (U. S. Mines Bur.) *Mining and Met.*, Vol. 22, Jan. 1941, pp. 5-8. Report of investigations.

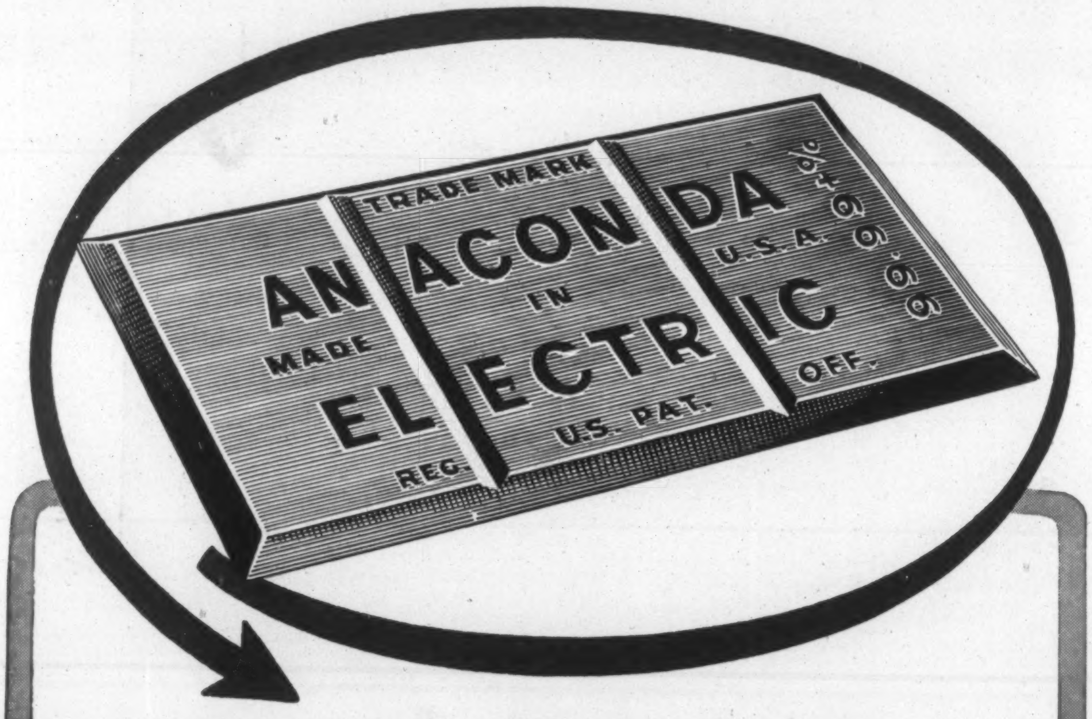
The production of electrolytic manganese is relatively simple. The manganese is introduced in the electrolyte in the form of MnO, which can be produced from the dioxide ores by a reducing roast at 500° to 550° F. At this temperature the iron in the ore is reduced to its most insoluble form, Fe_3O_4. The manganese thus produced is less subject to reoxidation.

The MnO formed is soluble in sulphuric acid and the pH of the solution can be brought up as high as 6.0 without using excessive time for leaching. Manganese carbonate ($MnCO_3$) is also suitable for introducing manganese into the electrolyte, but it is necessary to complete the neutralization with MnO or lime, involving a loss of sulphuric acid.

The electrolyte contains about 35 gm./1. of manganese as sulphate. To this is added 150-200 gm./1. of ammonium sulphate, and the solution is purified, using methods that vary according to the impurities in the ore. Iron and arsenic have been removed by bringing the solution to pH 5-6. A small amount of hydrogen sulphide purifies the electrolyte, and a filter aid collects the precipitated sulphides. The purified solution is treated with 1/10 gm./1. of sulphur dioxide.

The electrolyte is fed through the catholyte compartment of a diaphragm cell, where about half of the manganese is plated out as metal. The depleted catholyte is mixed with anolyte solution and returned to leach a new batch. A feature of an electrolytic manganese cell is the stainless steel cathode surrounded by a canvas diaphragm, which is porous and permits considerable manganese from the catholyte to flow into the anolyte. The anode may be lead or an alloy of tin, lead and cobalt. Another method of reducing manganese dioxide formation is by skirting the anode with cloth.

The current density used is about 20 amps./ft.^{2} Current efficiency is as high as 65 or 70%. Several modifications of the above process have been suggested, but they do not vary in their fundamental principles. [See "Electrolytic Manganese—Manufacture and Possible Uses," Metals and Alloys, Vol. 11, Jan. 1940, p. MA 47.] The elec-



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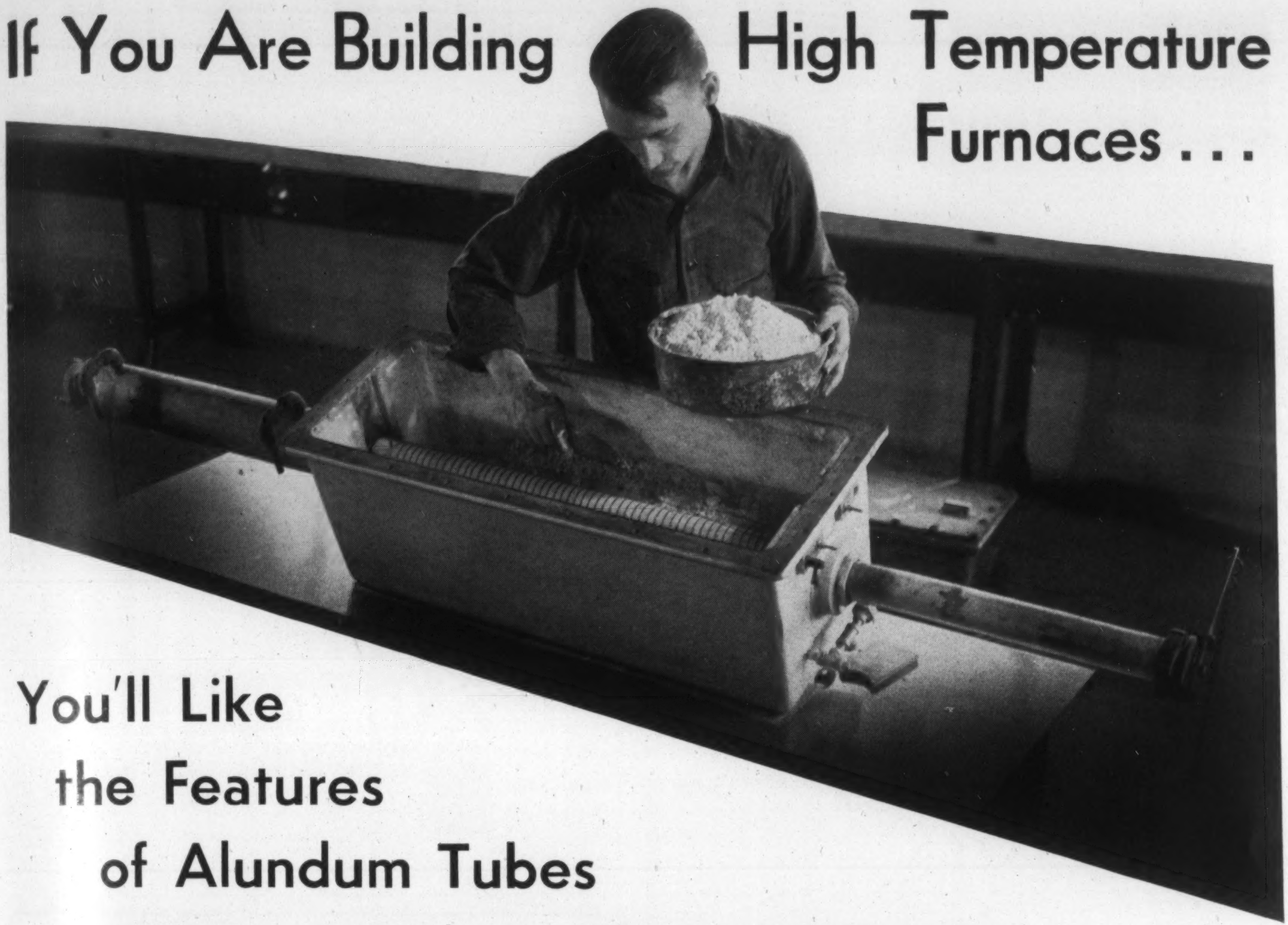

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trolytic manganese produced by the Bureau of Mines was very pure except for the presence of relatively large amounts of sulphur. This may be removed by treatment with borax in the molten state and subsequent removal of boron by manganese dioxide. The only other impurity present is iron up to 0.02%. Much of the manganese is accordingly 99.95% pure or better, and rarely less than 99.9%.

Pure manganese is brittle and one of its important uses is as an alloying element. In the steel industry electrolytic manganese can be used in many grades of steel. Comparison of properties of S.A.E. 1035 steel show no difference resulting from the use of blast furnace ferro-manganese, low-carbon electric furnace ferro-manganese or electrolytic manganese.

The best outlook for a good market for electrolytic manganese is its use in alloys high in manganese—manganese-copper alloys with unusually high specific vibration damping capacity, manganese-nickel-copper alloys with high coefficient of expansion, manganese-copper alloys with ultra-high specific electrical resistance, zinc-manganese-copper extrusion alloys of high strength and exceptional machining properties, and iron-manganese-chromium (26 Mn, 18 Cr) alloys that are stainless. VSP (1b)

Refining Aluminum Scrap

"Progress in Research and Control—Aluminum Refining." *Light Metals,* Vol. 3, Feb. 1941, pp. 32-33. Descriptive review.

None of the ordinary methods of refining aluminum scrap can be said to be very efficient, with respect to elimination of the impurities. The electrolytic method used in the production of virgin aluminum has not been widely utilized for scrap because of the high costs involved. The distillation process of aluminum purification may hold some promise, but at present it has not had enough use to justify evaluation.

However, among the processes in use today, the electrolytic method is the only one easily capable of producing metal of the desired purity. A recently reported investigation provides some interesting data on the electrolytic refining of aluminum containing iron, copper, zinc, silicon and manganese, using an electrolyte of 38% $AlCl_3$, the remainder NaCl.

The work was on a very small scale: 300-c.c. capacity cells were used at first, then 2-liter capacity cells. The cells were of porcelain, and were heated in a crucible furnace. The anode alloy was placed in the bottom of the cell and was of such a composition that the melting point was not over 1475° F. The current was led to the anode by a graphite rod protected from the salt by a porcelain sleeve.

A "sinter-corund" beaker was placed on the bottom of the cell and was used to collect the refined aluminum. The cathode was a graphite rod protected at its upper extremity by a porcelain sleeve and situated over the sinter-corund beaker. After the salt had been melted down over the anode alloy in the bottom, the temperature was adjusted to 1475° F. and the electrolysis carried out for several hours. While the anode efficiency was usually about 100%, the cathode efficiency was somewhat less, owing to loss of some fine aluminum powder and to carbide formation.

Aluminum-copper alloys containing 15 and 37% Cu were investigated. With an anodic current density of 1.0 amp./cm.^{2}, no trace of copper could be found in the refined aluminum. Using a current density of 0.7 amp./cm.^{2} with an aluminum alloy containing 7% Fe as the anode, 0.003% Fe was found in the cathode aluminum; at 0.4 amp./cm.^{2} no iron could be found. With aluminum-zinc alloys of 8, 15 and 27% Zn, transference of zinc to the cathode was found. Manganese in the anode was limited to 8% owing to the melting point restriction, and in most cases no traces of manganese found their way to the pure aluminum.

Experiments with a 10% Si alloy were complicated by the tendency of the silicon-containing anode alloy to attack the porcelain in the system; bits of porcelain would be found in the cathode metal, where reduction of the porcelain to silicon could occur. When the sinter-corund container was lined with nickel, however, and a nickel cathode rod was substituted for the graphite rod, the silicon was eliminated. It was concluded that there was no electrochemical transference of silicon to the cathode.

In some of the larger-scale experiments, it was found that when an anode alloy of 10-13% Si and 2-18% Fe was used with a current density of 1.0 amp./cm.^{2} the silicon content of the refined metal did exceed 0.09%, while the iron was present only in traces. Over 18% Fe in the anode, however, resulted in an iron content of 0.38% in the refined aluminum. In refining aluminum of commercial purity (0.2-0.33% Fe), the iron was almost completely eliminated, but the silicon was not eliminated as efficiently. The silicon content was the same as that obtained when refining the aluminum-silicon alloy "Alpax," showing that the residual silicon is due to mechanical contamination from parts of the apparatus.

Metal as pure as 99.98% Al or better was obtained starting with various aluminum alloys. It is quite likely that this process could be carried out with success on an industrial scale. To prevent carbide contamination, the end of the cathode not covered by the protective tube is fitted with a cover made of a porous silica-free material. Aluminum liberated at the cathode soon fills up the pores in the cover, and the surface becomes metallized. After this aluminum coating has formed, aluminum is liberated on the metallized surface and prevents the aluminum from reacting with the carbon cathode. AUS (1b)

Gating Non-Ferrous Castings

"Gating Non-Ferrous Castings Is Important." N. K. B. Patch. *Foundry.* Vol. 68, Nov. 1940, pp. 40-41, 90-92; Dec. 1940, pp. 38-39, 108-111; Vol. 69, Jan. 1941, pp. 46-47, 112-114. Practical.

The first essential of good gating is to provide the right-sized sprue with the necessary capacity to give ample flow of metal, but not so large as to develop spiral spinning of metal as it flows into mold. A turbulent condition will develop defective spots due to mixing of dross with the metal. The top of the sprue should be rounded and funnel shaped.

In some cases, as in yellow brasses without aluminum, it is desirable to have gates of ample size to insure rapid filling of the cavity and thus avoid scum spots. The size of both are riser and gate is of great importance. The flow of metal into the horn should be controlled by the size of the runner leading the metal to the horn. The size of the gate should be slightly less than the horn gate opening into the mold, thus eliminating squirting. The surest method of having clean metal is to have the right-size sprue, and to keep it full to the top to insure that the scum will remain on top of the sprue.

In large castings with very heavy sections and especially with light and heavy sections adjoining made from high shrinkage alloys it is often nesessary to repeat the filling of the riser several times. If the neck or passage between the riser and casting is restricted, the restriction often freezes and prevents the flow of metals. Any ingress to or egress from the casting must be designed to avoid sharp corners, and fillets should be provided at the junction of gate and casting, and of casting and risers.

The square or rectangular riser offers the maximum area for radiation of heat as compared with the volume of metal it holds. Therefore, if the riser is to be kept molten for a long period it is better practice to use a round riser. Also, in the round riser, after the first crystals set, they set in uniform rings parallel to the sides of riser and uniform cooling takes place, with the final setting occurring at the center.

Very simple shapes can be produced by pouring through the riser without gates and sprue, but the chances of making a high percentage of good castings are reduced. Often pouring is done through the right size of sprue and then through a gate leading into the base of a riser. An advantage of this type of gating is that the last metal poured into the mold is that which finally fills the riser. The riser temperature is higher than the metal temperature in the mold, and therefore the riser will be molten after the metal in the mold has set.

One disadvantage of such gating is that the riser must be connected with the heavy section of casting to provide feeding as the casting solidifies. The heavy section may be at the top or bottom; then, as the riser fills, the metal spills over the edge into the lower part of mold and may form dross. Where 2 or more risers are used they should be of adequate height to provide the necessary static pressure to force the metal from the risers; if one riser is too small, the other two have to do the feeding, and this causes a shrinkage cavity at the base of the riser or possibly at the casting.

Changes in design, even though minor, may increase the demand for proper feeding and thus make a riser necessary that otherwise might have been omitted. Sometimes the situation may be taken care of by increasing the thickness of the gate or by adding a shrink ball. Increased thickness should be sufficient to insure the metal's remaining molten until after the casting has set and to provide proper feeding at points where gates enter.

A change in composition or alloy being cast may necessitate a definite change in gating, the amount of risers demanded, and their proper connections. For example, a 12-in. straight bushing, with wall thickness of ¾ in. and outside diameter of 4-5 in., if cast in red brass, should have gating so designed that metal enters the mold quietly. The metal should be led from one end of the bushing to the other in such volume that the metal does not spread in thin layers before the mold begins to fill. Many foundrymen cast such bushings on their sides. Casting this bushing in manganese bronze requires a gate designed to prevent the agitation of the metal; ample risers must also be provided. VSP (1b)

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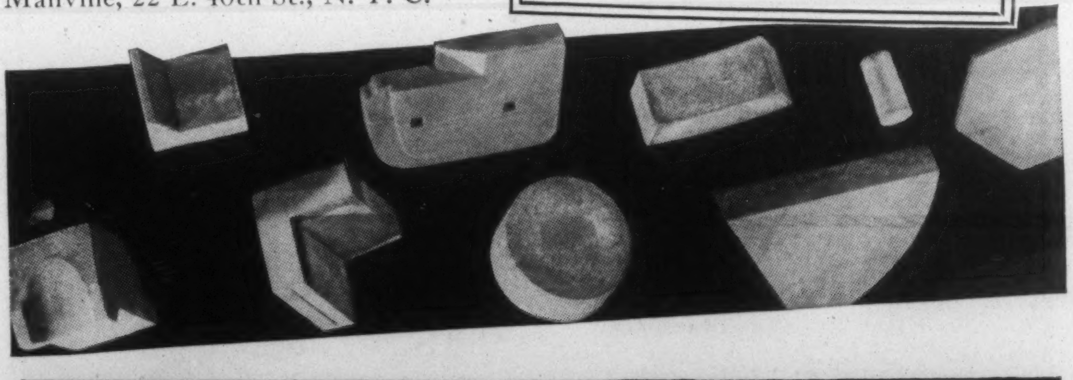

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Arc Welding Electrode Coatings

A Composite

The number of fluxes used for arc welding electrode coatings is large, and evidently growing. Flux compositions have seldom been the subject of specifications, and each electrode manufacturer has developed a long series of coatings after research based on the many electrode user's varied requirements. When this diversity is multiplied by the number of electrode manufacturers, the situation is seen to be one ripe for standardization.

Considerations of this type led W. ANDREWS ("Some Observations on Metallic Fluxes," *Welder,* Vol. 12, Mar.-Apr. 1940, pp. 57-59; May-June 1940, pp. 93-95) to review and broadly classify the types of electrode available for mild steel and to examine each from the engineering viewpoint.

The flux coating on a metallic arc electrode is effective in controlling the electrical characteristics of the arc, in modifying the mechanism of metal fusion and consequently transmission across the arc, in affecting metallurgical reactions occurring in the molten weld metal during its passage through the arc, and in influencing the shape and surface finish of the resultant welding bead. The majority of modern fluxes consist of a mixture of minerals, chemicals and alloys homogeneously bonded with an alkaline silicate solution. Subsequent drying gives a hard cement of reasonable permanence.

The silicate solutions used as the binding agent are either sodium or potassium silicates, used separately or mixed in various proportions. The actual compositions of the flux powders usually remain manufacturers' secrets, and little information has been published on them. In most commercial mild steel electrodes, they usually consist of mixtures of mineral silicates, ferro-alloys, metallic oxides, fluorides and carbonates, and organic compounds.

One essential for a flux ingredient is that it should be inert to the silicate used as a binder. Ordinarily, however, the flux material need not be completely insoluble, so long as the product is neutral in reaction. The most frequently used of the various materials are kaolin, soda and potash feldspars, various grades of iron oxides, oxides of manganese, titanium oxide as rutile, ferro-manganese alloys, sometimes ferro-silicon, ferro-titanium and ferro-vanadium, and all forms of calcium carbonate commercially available.

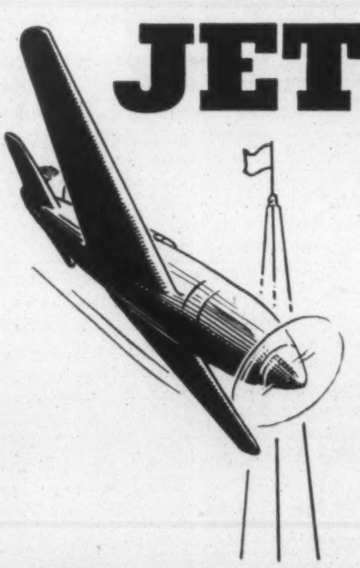
True fluxes, in addition to exercising their effect on the electrical characteristics of the arc, are employed for their metallurgical and mechanical effects on the deposit. According to whether they contain cellulosic matter and are of the so-called gas-shielded type, or rely on the fluxing properties of the chemicals or minerals they contain, they may be divided into slag-shielded types or gas-shielded types. Further, fluxes may be subdivided by method of manufacture, *i.e.* dipped, wrapped, wound-extruded or plain-extruded.

Automatic Arc Welding

Somewhat more specific flux requirements are listed by WILLI M. COHN ("Review of Fluxes Used for Automatic Arc Welding," *Welding Engr.,* Vol. 25, Sept. 1940, pp. 17-19) for automatic arc welding. In this type of work the welding operation is entirely automatic, except for starting the machine and replacing, from time to time, the electrode and flux.

The desirable properties of a flux for automatic arc welding are: (1) The oxidation and nitration of materials from the electrode and of the weld proper should be prevented. (2) The electric arc should be stabilized and its ignition and re-ignition should be facilitated. (3) Impurities from the electrode and the base metal should be removed. (4) Sputtering of metallic particles should be prevented.

Furthermore, a slag should be formed that will quickly rise to the surface of the molten pool in order to prevent non-metallic inclusions and pores in the weld; the slag should form a protective, solid coating over the freshly-deposited weld metal, and protect it against oxidation and nitration; the slag should retain enough heat to prevent too fast cooling of the weld; the slag should be easily removable or should automatically peel off the weld after cooling.



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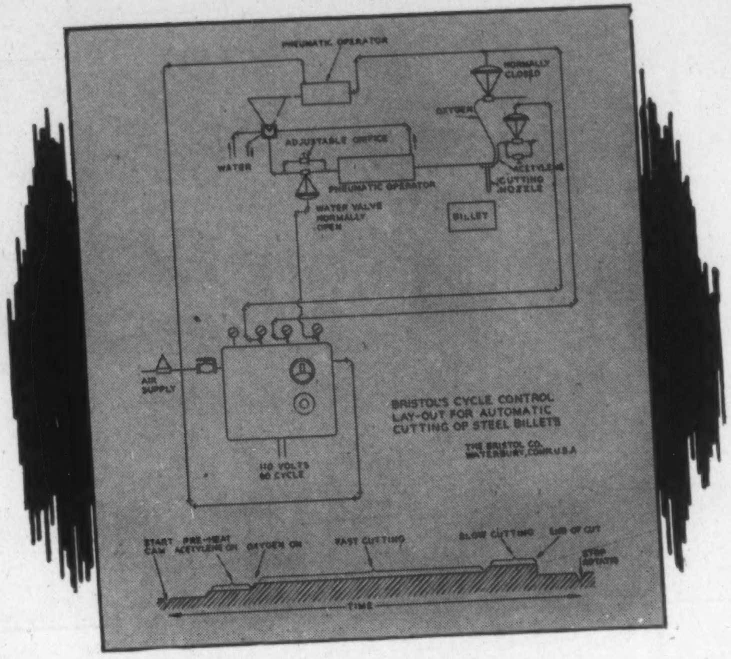
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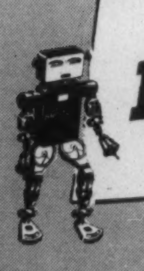

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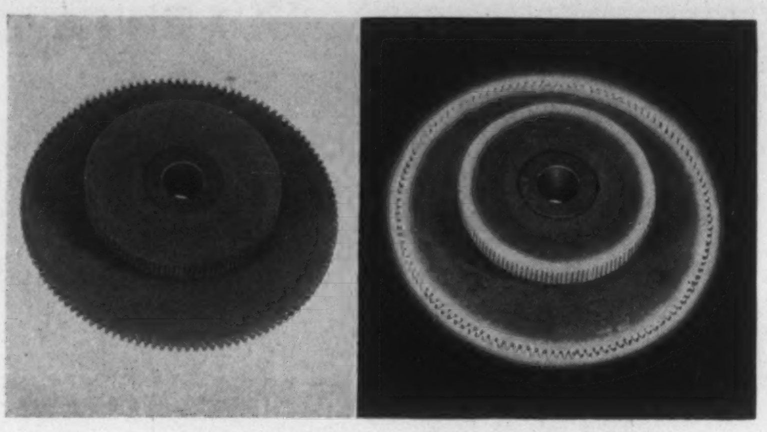

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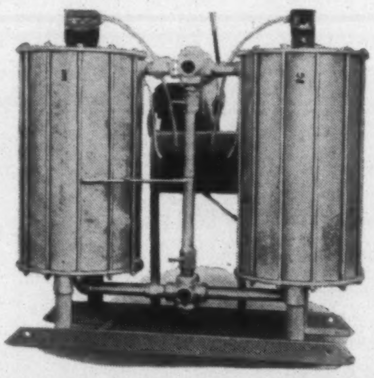

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Also, it should be possible to add certain ingredients to the base metal if desirable —such as manganese, titanium, and molybdenum. Finally, all reactions during or immediately following the welding should be completed at the highest possible rate of speed in order to assure great rapidity of welding.

The composition of the flux used in coated electrodes for automatic electric arc welding is similar to that used for hand welding. Although powdered flux has been used for many years, the modern development of automatic electric arc welding may be dated from the patent issued in 1930 and assigned to the National Tube Co. The patent gives few details regarding the composition of the flux.

Most fluxes used for this type of work are a mixture of various raw materials, chiefly raw natural clay. One patent assigned to the General Electric Co. discloses a flux containing 18% titanium dioxide, 53 feldspar, 1 raw bentonite clay, 4 sodium hydroxide, 2 sodium carbonate and 22 water.

In a 1936 patent assigned to the Union Carbide & Carbon Corp. a flux is described that comprises 31% calcium oxide, 11 magnesium oxide, 52 silicon dioxide and 4 aluminum oxide. Whereas former patents make use of raw materials that are likely to give off water vapor, this flux is melted in an electric furnace prior to its use as flux; it will produce welds that are considerably better than hand welds.

A very recent patent (1940) assigned to the Western Pipe & Steel Co. describes a flux of 57.6% aluminum oxide, 41.8 silicon dioxide and 0.6 titanium dioxide. The raw material is processed by heating it to a temperature of about 2200° F. and maintaining it at this temperature for a considerable length of time. CEJ (2)

2a. *Ferrous*

Pipe Welding in Power Stations

"PIPE WELDING, BURLINGTON GENERATING STATION," PHILIP SALMON (Public Service Elec. & Gas Co.) *Welding J., N. Y.*, Vol. 20, Jan. 1941, pp. 5-9. Descriptive.

Steam conditions at the job described are 1250 lbs., 960°F. at the turbine throttle. Pipe welds in carbon steel and carbon-molybdenum steel base are welded with cellulose - coated carbon - moly electrodes using the same type of backing ring and scarfing detail.

In previous work requiring preheat, the requirement of constant temperature from start to finish of weld was costly where an unfinished weld remained so overnight. In the present installation it was found that after 3 layers of weld metal have been deposited the joint can be cooled overnight and completed next day without crack formation.

Newly available fittings and valves designed for welding make possible simpler procedures and a higher quality product. Some tests were made with 19¼ in. O. D. pipe of 1⅛ in. wall to determine the effect of various root spacing.

Preheating and stress relieving are performed by an induction winding on the pipe, using a 60-cycle low-voltage current. Stress relief at 1150°-1200°F. for 2 hrs. per in. of wall thickness is the usual procedure. A section may be removed from the weld joint by means of a power driven metal saw, which is portable and produces a boat-shaped specimen for macro-inspection after etching. Bend tests show uniform ductility across 1 in. pipe wall. WB (2a)

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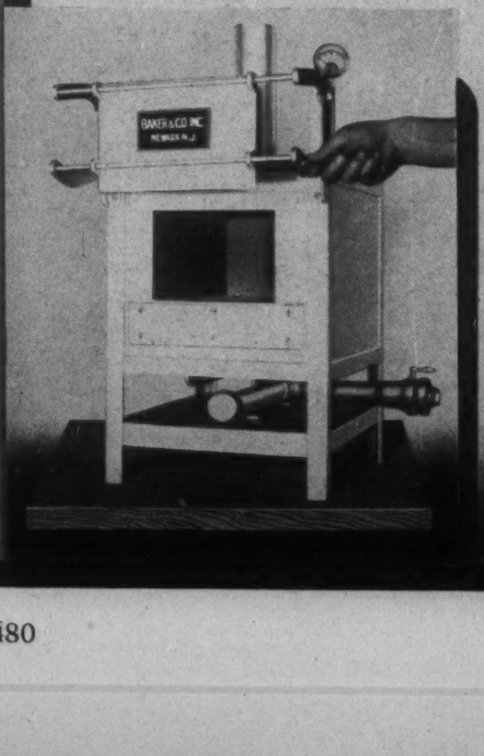

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Welding, Cutting of Wrought Iron

"Welding and Flame Cutting Wrought Iron." Harold Lawrence. *Steel*, Vol. 107, Dec. 9, 1940, pp. 84, 87. Practical.

In welding wrought-iron, the slag must be floated out of the weld-metal. Fusion welding may be done with the metallic arc, the carbon arc, and the oxyacetylene torch, either manually or automatically. While wrought-iron is non-hardening, it is good practice to stress relieve welds in thick plates at 700°-800° F.

In metallic arc welding, a lower wattage and slower speed of travel should be used to maintain a quiescent pool of metal, thereby allowing time for slag to float out of the deposit. All-position and downhand electrodes are preferable. An adequate bearing surface should be used for all fillet welds to counteract the weakening effect of the silicates in wrought-iron. Butt welds are best made with all-position electrodes, while fillet welds may be deposited either with this type of rod or with a mineral-coated downhand rod.

The horizontal fillet weld class of downhand rod is recommended for horizontal fillets in material ¼ in. thick or heavier. Material of more than ⅜ in. thickness works well with electrodes used for mild steel of the same thickness, except general purpose electrodes for stringer bead fillet welds. There are, however, applications in lighter gages where the general purpose rod will produce acceptable welds at low cost.

In oxyacetylene welding, the greasy appearance of molten slag (which has a lower melting-point) must not be confused with the slick appearance of melting metal. As soon as the operator learns to distinguish between the two, welding may progress in the same manner as in welding mild steel. Excessive melting of the base metal should be avoided.

Almost all carbon arc welding of wrought-iron is done automatically, using fluxes. Reported speeds for ⅜ in. plate in both wrought-iron and mild steel are 40 ft./hr. of completed weld.

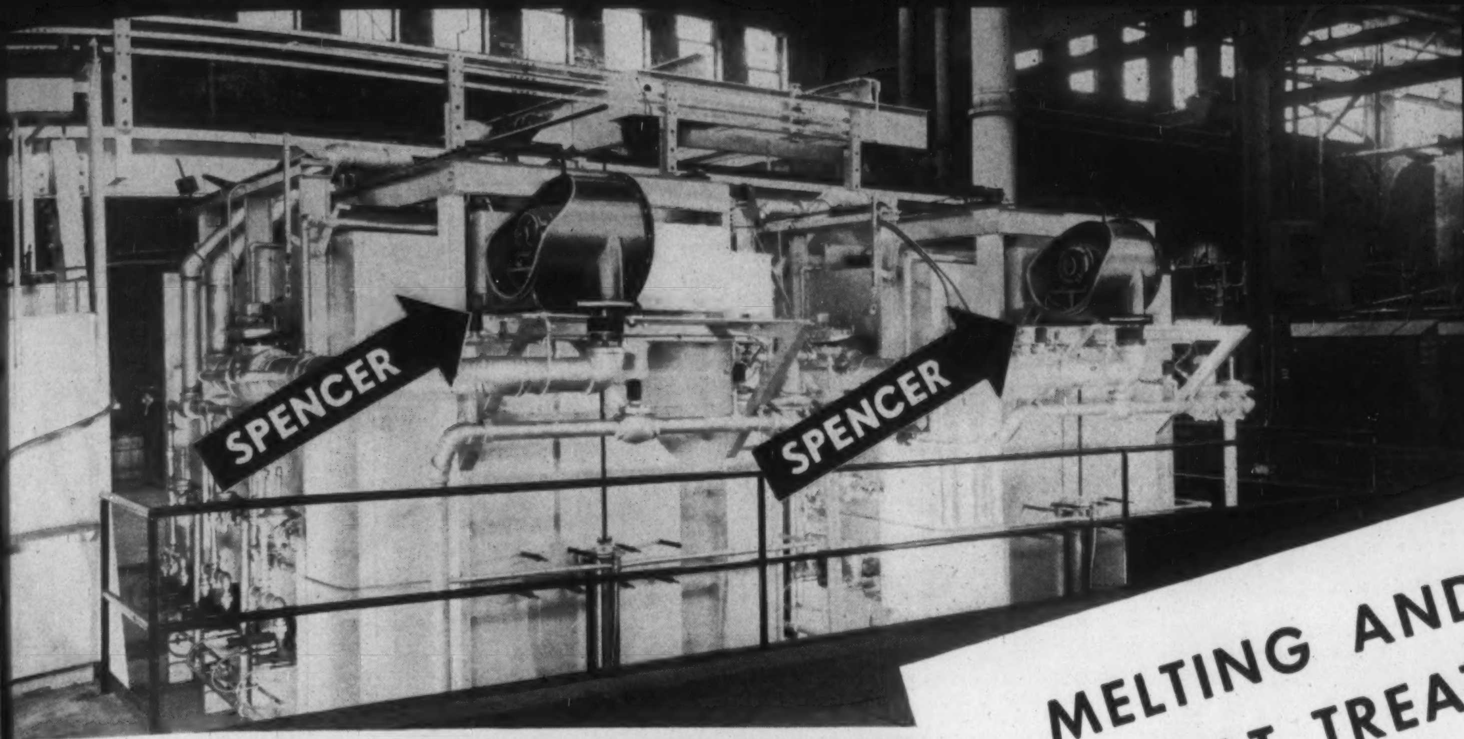
Wrought-iron can be readily cut with the flame by using slow speeds with considerable preheat. It is best to use a 6-hole preheat tip rather than the usual 4-hole tip, and a tip one size larger than commonly used to cut steel. Lower oxygen pressures should be used. MS (2a)

Heating Treating Behavior of S.A.E. 4140

"Influence of Austenite Grain Size Upon Isothermal Transformation Behavior of S.A.E. 4140 Steel." E. S. Davenport, R. A. Grange & R. J. Hofsten (U. S. Steel Corp., Res. Labs.) *Metals Tech.*, Vol. 8, Jan. 1941, 10 pp. Research.

Increasing the austenite grain size in an S.A.E. 4140 steel from 7-8 to 2-3 A.S.T.M. grain size units greatly retards the isothermal transformation of the austenite at higher temperature levels, about 1050° F. and above, where soft lamellar structures form. At lower temperature levels where the structures are acicular, grain size has no appreciable effect on the speed of transformation of this steel.

The effect of grain size on the rate of transformation to proeutectoid ferrite and lamellar products varies with the temperature level, being greatest just below the Ae_1 temperature and decreasing in intensity as the transformation temperature level approaches 900° F. Coarse-grained austenite in 4140 tends to reject less free ferrite



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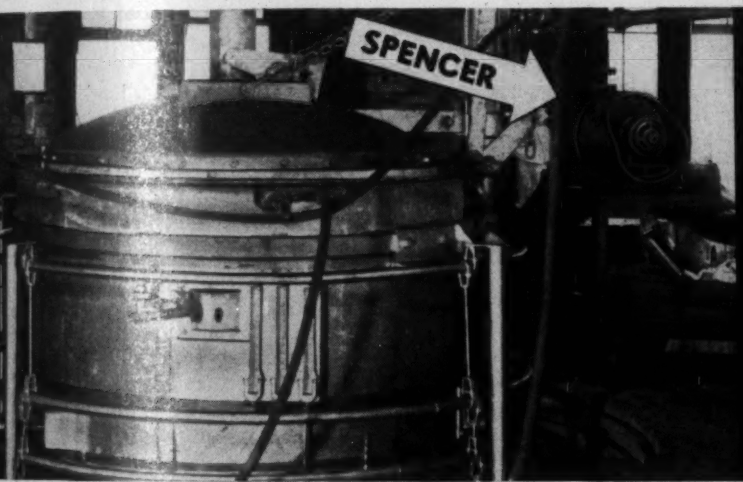

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Phosphate Coating Treatments

Quantitative Investigation of the Protective Layer and the Self-Passivating Process in the Phosphating Bath (Quantitative Untersuchung der Deckschicht und des Selbstpassivierungsvorganges in Phosphatierungsbädern) Willi Machu. *Chem. Fabrik,* Vol. 13, Dec. 14, 1940, pp. 461-470. Research.

Phosphate coatings on electrolytic iron specimens were examined by electrolytic methods, using the Müller surface relation law, $t_p = B(i_o/F_o - F)^{-n}$, to express the pore surface area. In this equation t_p is the passivating time, i_o is the current intensity, B and n are constants whose values are determined by the metal and electrolyte used, and $F_o - F$ expresses the pore area.

Tests were made on the Coslett, Atramentol and the Parker processes. In all three baths a value of 0.003 cm.^{2} of free pore surface per cm.^{2} of total surface was obtained. This compares generally with the natural oxide layer on iron.

It was found that the phosphating process did not stop when hydrogen evolution ceased, but that the pore area was further diminished about 1/100 to 1/10 and the thickness of the coating increased about 30% by continued treatment afterwards. Gravimetric determinations of the pore area and coating thickness checked the results of the electrolytic test. In spite of the increase in coating thickness and decrease of pore area after the end of the hydrogen evolution, the corrosion resistance was only slightly increased.

Coating iron with a phosphate layer is a typical "self-passivating" process. This passivity causes the potential of iron to be ennobled about 0.10 to 0.25 volts. A preliminary pickling treatment of the iron delays the formation of the phosphate layer, possibly through the removal of the minute and chemically active surface projections produced by grinding or sand blasting. A lowering of the bath temperature also greatly delays the deposition of the phosphate.

With the help of the Müller equation, the conductivity of the electrolyte in the pores of the coating can be ascertained. The low value which was found was attributed to the saturation of the free phosphoric acid on the iron surface by iron. The electrical resistance of the pores was found to be about 2000 ohms for a normal solution of sodium sulfate as determined from current-potential curves. PCR (2a)

Oxy-Propane Cutting

"Cutting Steel With Oxy-Propane." Wm. T. Tiffin (Univ. Okla.) *Iron Age,* Vol. 146, Dec. 12, 1940, pp. 61-64. Investigation.

The use of propane as a fuel in the oxygen cutting of steel is rapidly increasing. The clean cut surface which results from the use of propane and the comparative light weight of propane handling equipment together with its comparatively low cost, assure this fuel a future in this particular application. Steel foundries find propane an economical fuel, and use it in the cutting of risers from steel castings or for surface cleaning. Thicknesses up to 34 in. have been cut with the oxy-propane cutting torch.

The factors that have to be considered before determining the best procedure were control of cutting speed, fuel gas and oxygen supply, cutting technique, gas pressures, and reproducibility. In the tests reported here, the oxygen was of commercial grade and cost 1¼c/ft.^{3} Propane was also a commercial grade, costing 5c/gal. The oxygen pressure on the cutting jet varied slightly around 40 lbs./in.^{2} gage. Higher pressures caused more "blowing" of molten metal with consequent increase in cost. The propane pressure on the preheating jet was between 2.5 and 5 lbs./in.^{2} gage.

Optimum preheating flame conditions were determined as follows: When the propane is ignited, the flame is yellow, and somewhat erratic. As the oxygen valve is opened the flame straightens out and the characteristic Bunsen burner flame is noted. As the oxygen increases, the inner flame becomes shorter. At a definite point the inner flame ceases to shorten, and further increase of oxygen *lengthens* the inner flame. The proper flame adjustment is obtained at this instant, with the inner flame at its shortest length.

Regulation of oxygen pressure was first obtained at the cylinder where reduction to 75 lbs. gage was maintained. On the discharge end two-stage reduction was obtained, first supplying oxygen to the cutting jet, and second to the preheating jets. Single stage reduction of propane was obtained after passing it through a hydraulic water seal. Propane pressure was about 104 lbs. gage before reduction to flame pressure. The cutting torch was carried by an electric cutting machine traveling on straight track, and the cutting tips were interchangeable.

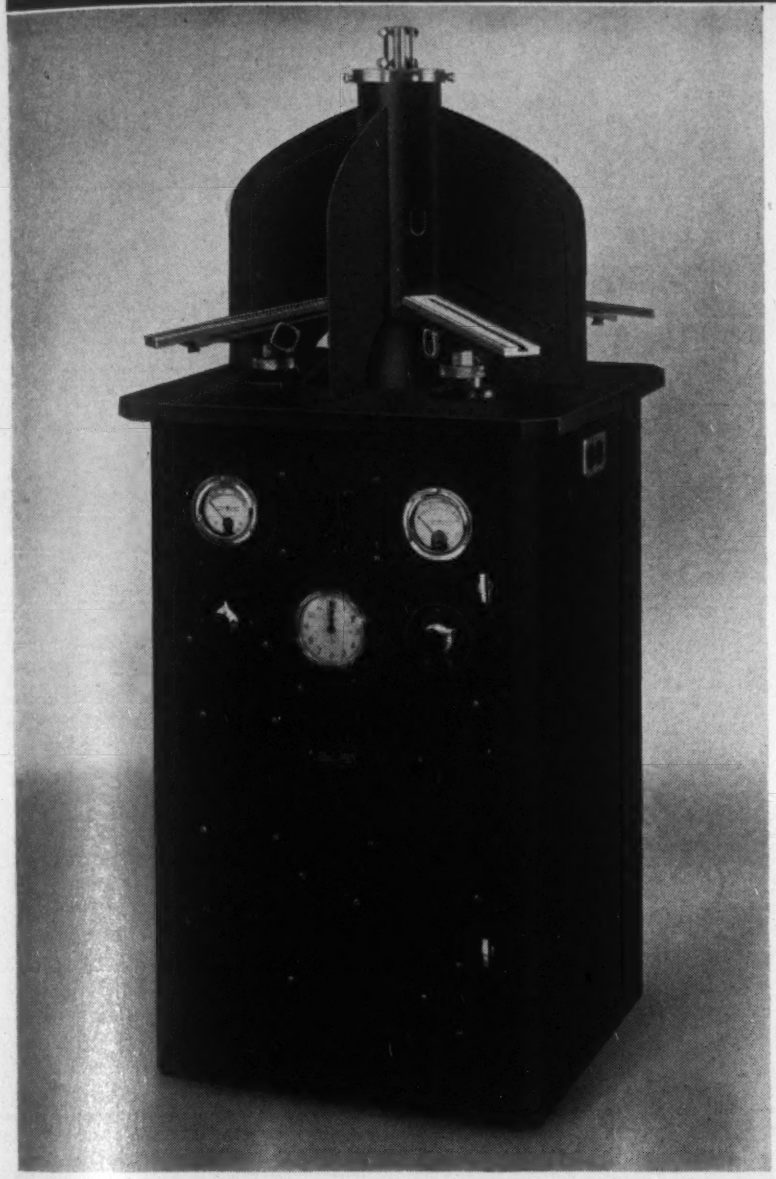
Representative costs for oxy-propane cutting of steel, as determined in the author's tests, are given in the Table.

Metal Thickness, In.	Cut Speed, Min.	Gas Consumption Cu. Ft. Per Min.		Cost of Cut, Cents	
		Oxygen	Propane	Per Ft.	Per Sq. In.
0.25	29.0	1.14	0.04	0.59	0.197
0.50	24.0	1.31	0.06	0.82	0.137
0.75	20.0	1.52	0.06	1.14	0.164
1.00	17.5	2.42	0.08	2.09	0.174
1.25	16.9	2.97	0.12	3.18	0.212
1.50	16.0	4.43	0.122	4.16	0.231
2.50	11.1	4.81	0.125	6.02	0.201

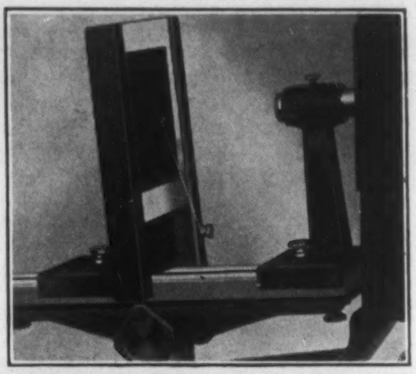
It can be seen that in the thicker plate, over 2 in., more sq. in. of metal are removed per unit of cost than in thinner plates. Advantage may be taken of this fact when cutting thin plates and producing duplicate parts, by stacking the plates on top of one another and clamping securely together.

Greater cutting speed may be secured only at a sacrifice of cut quality. Cost

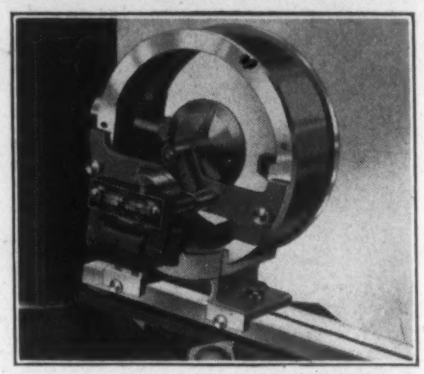
The G-E XRD X-Ray Diffraction Unit



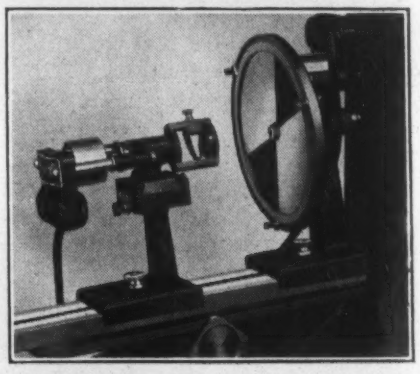
The XRD Pinhole Assembly and collimator tube support in use with flat cassette and cassette holder for 3¼" by 4" films.



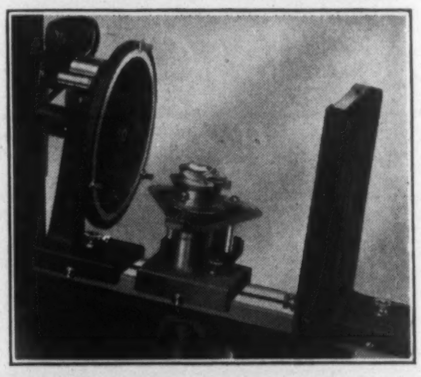
The XRD Powder Camera with oscillating specimen holder in position. Standard equipment also includes rotating specimen holder to be used with capillary tubes, and a septum which divides the camera so that a reference pattern may be placed upon one half of the film.



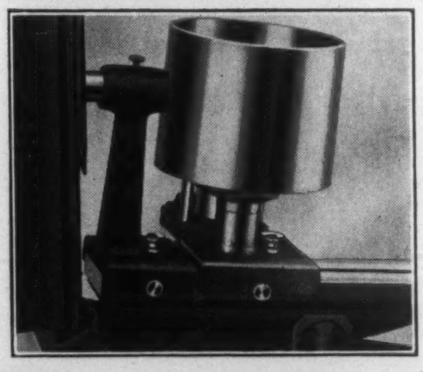
The XRD Back Reflection Camera and rotating specimen holder—a high-precision instrument for the exact evaluation and comparison of lattice parameters in the study of metals and alloys and other crystalline structures.



The XRD Universal Specimen Mount may be used with the Pinhole Assembly and flat cassette for Laue and rotation patterns, with the Back Reflection Camera for Sauter patterns and for back reflection Laue patterns, or with the Cylindrical Cassette and the Pinhole Assembly for oscillation and rotation patterns.



The Cylindrical Cassette which is furnished with the XRD Universal Specimen Mount for use with the Pinhole Assembly. The Cylindrical Cassette is mounted on the goniometer head which has fine screw adjustments on the arcs and for centering the specimen in arcs.



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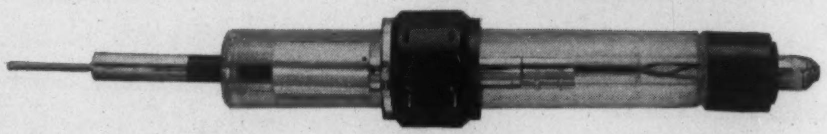

The G-E Model CA-4 Crystal Analysis Tube with four Lindemann glass windows and protection shield. Tube is available with complete x-ray protection shields which extend to cover both arms of the tube and includes x-ray proof stoppers for the ports of the tube which are not in use.

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varies inversely as the plate thickness. The highest cut quality is obtained together with minimum oxygen and fuel cost per unit of length, and the cost per unit volume of metal-removal decreases as the plate thickness increases. VSP (2a)

Electropolishing Stainless Steel

"The Electrolytic Polishing of Stainless Steels." H. H. Uhlig (General Electric Co.) *Trans. Electrochem. Soc.*, Vol. 78, 1940; Preprint No. 25. 8 pp. Research.

Electrolytic polishing of 18/8 stainless steel is less expensive and time consuming than mechanical procedures. A solution of ortho-phosphoric acid containing certain organic additions was found to be a satisfactory electrolyte, as the metal loss was low, there was no pitting, and low current densities could be used. The degree of polish obtained under different conditions was determined with a photo-electric spectrophotometer.

The optimum polish was obtained with an electrolyte consisting of 42% H_3PO_4, 47% glycerine and 11% water, used at 212° F., or above, with an anodic current density above 1.5 amps./dm.^{2} The time required varied from 75 min. at 1.5 amps./-dm.^{2} to 15 min. at 8 amps./dm.^{2} A specular reflectance of 93% was obtained as compared with 23% for the original cold-rolled finish. The amount of metal removed amounted to about 0.0004 in.

Other steels could be polished in the above electrolyte, but the operating conditions had to be changed somewhat. A polish could be obtained on mild steel with a 50 vol. % carbitol-phosphoric acid mixture at 125°-175° F. and a current density of 8-16 amps./dm.^{2} One function of the glycerine is to prevent attack of the anode by chemical action, independent of anodic attack. AB (2a)

Welding Naval Piping

"Investigation of Welding for Naval Piping." Bela Ronay (U. S. Naval Eng. Expt. Sta.) *Welding J., N. Y.*, Vol. 20, Jan. 1941, pp. 25-39. Review plus research.

Thin-wall pipe-welds of three different designs in 2-in. I.P.S. and smaller pipe were investigated for fatigue resistance as a rotating beam with the welded joint in the center. The flow resistance of pipe interiors was determined and found to be a minimum where interior streamlining is achieved by proper design.

Stress relieving of joints does not materially increase the fatigue strength but gives more consistent results. The above tests made on arc-welded material were duplicated on oxyacetylene-welded specimens. The fatigue strength of the latter was higher; the cost of the joints was somewhat higher but the quality and appearance was improved, especially in the smaller diameters.

For welding thick-walled tubing below 2 in. I.P.S., a non-metallic backing ring was employed. During welding the rings are partially burned and collapse; they can be removed from the interior by mechanical or other means. Full penetration is obtained by the proper arc-welding procedure in using the 45° bevel kerf as the starting point for the arc. Another successful procedure for obtaining good streamlining and root penetration is composite welding, in which the pipe ends are initially joined at the root by means of thermit reaction heating and pressure push-up. The weld is then completed with the arc.

Tests on thick-walled piping 2½ in. I.P.S. and larger are described for 3 types of joint: (1) open-root U, with a ⅛ in. thick medium steel backing ring welded with a fillet into the tube end—which in the joint represents the inlet; (2) conventional 60° included-angle groove with 3/16 in. steel backing ring, also welded into the inlet side; (3) weld made with a nonmetallic backing ring. Type (3) joints were made with the minimum of 5/16 in. root-spacing since it was found to be impossible to obtain sound root conditions consistently with narrower spacing.

Type (1) and (3) joints were modified for vertical assemblies with welding proceeding with a weaving motion along a zig-zag path inclined about 45° from the vertical. In some of the welds tested in root bends the tack welds were not remelted and produced unsound root conditions; a holding clamp was therefore developed which eliminated the necessity for tack welding and gave uniform soundness at the root.

It is the author's opinion that residual stresses in pipe welding are present, and therefore it is good sense to remove the stress by heat treatment even though at the present there are no available data as to whether an early failure will beset non-stress-relieved joints installed in high-pressure, high-temperature steam lines. A magnetic method of demonstrating the character and magnitude of residual stress in pipe welds is described. The image of the distorted wave produced by the unbalance be-

Welder puts finishing touches on snow plow (Carl H. Frink).

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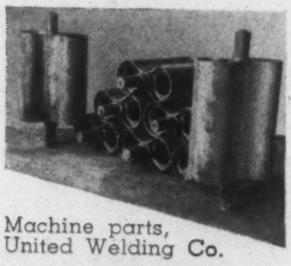

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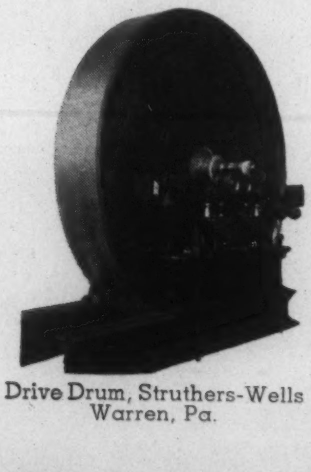

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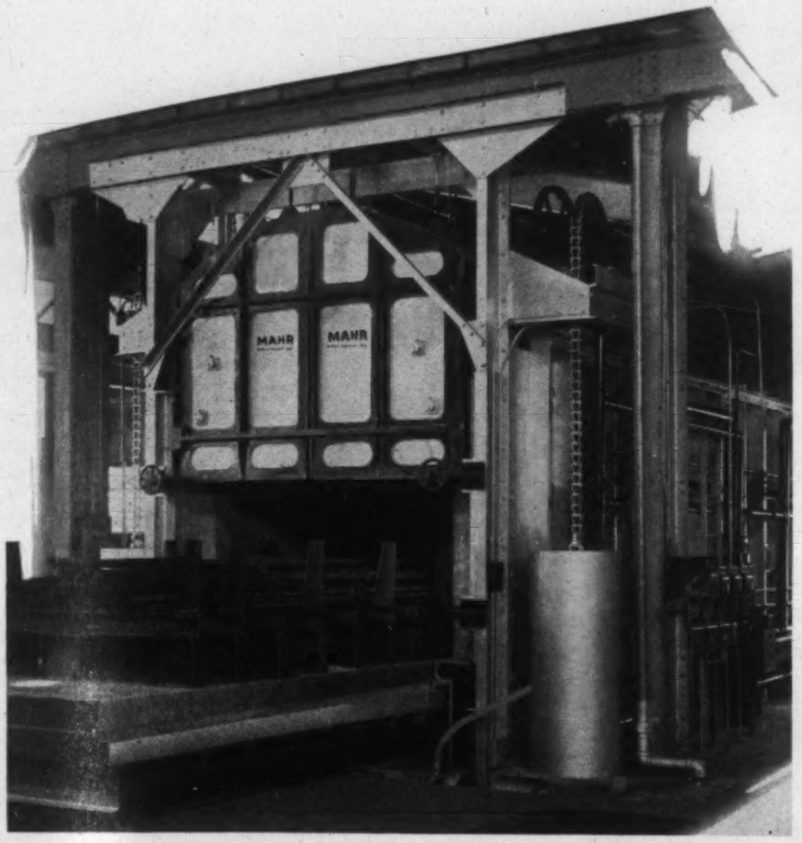

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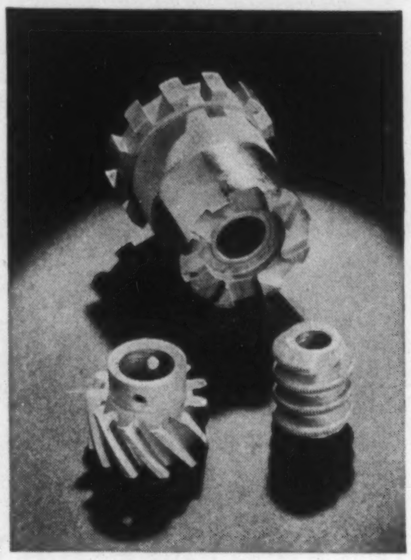

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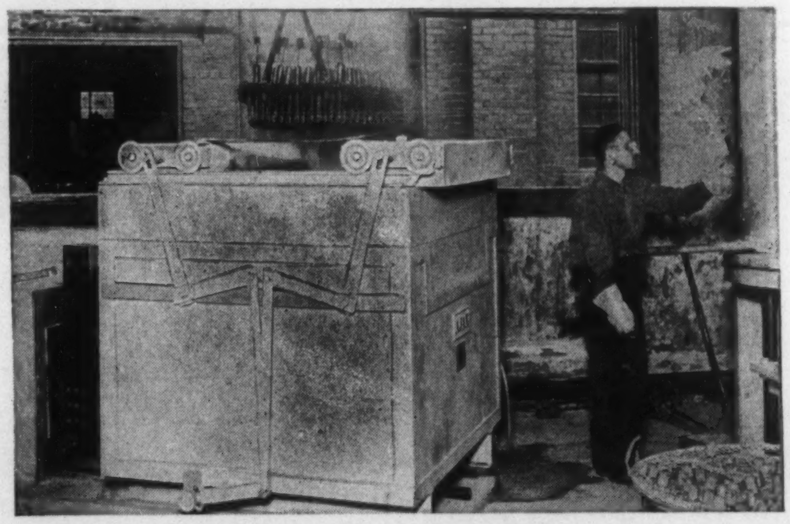

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tween a piece of steel without residual stress and the joint being tested is received on the screen of an oscillograph. A section of pipe in the as-welded condition was shown to have a residual stress in excess of 25,000 lbs./in.^{2} by this means; the stress was reduced to 2500 lbs./in.^{2} by stress-relief heat treatment.

The use of preheat in welding does not necessarily result in lowering the residual stress—in fact, in heavy-walled tubing the opposite may occur. Since practically all tube joints for high pressure, high temperature service are stress-relieved, a high residual stress due to preheating and welding is of no serious consequence. Preheating is considered to be of considerable advantage in preventing the formation of undesirable and (brittle) metallurgical structures in air-hardening steels; also, a greater volume of weld metal may be kept liquid in the crater with preheat, thus enabling the venting of occluded gases. There are several other advantages.

Of the 3 methods of stress-relief investigated, radiant heating in an "atmosphere" furnace, induction heating, and non-inductive direct-resistance heating—the induction method is preferable. The desirability of supplementing root and face bend tests for weld metal soundness with visual examination of macro-etched specimens is noted. For non-destructive tests, the magnetic powder method of examination is effective only when the re-enforcing is machined off; gamma-ray radiography was found to be unsatisfactory.

WB (2a)

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Spot-Welding Dissimilar Steels

"ELECTRO-MAGNETIC STIRRING ACTION IN A SPOTWELD." A. M. UNGER, H. A. MATIS & W. A. KNOCKE (Pullman-Standard Car Mfg. Co.) *Welding J., N. Y.*, Vol. 20, Jan. 1941, pp. 42-47. Investigation.

An analysis is made of the electro-magnetic forces acting on the liquid conductor in the weld portion of the circuit.

Various stages of the violent stirring action in the weld are shown by means of macrographs of the weld between a low-alloy steel and stainless. Considerable contrast can be obtained between the two melts at various stages in the mixing process by etching either electrolytically in chromic acid or with Nital. The macrograph of the path of stirring motion corresponds with the path theoretically derived.

The weld bead of the low-alloy stainless combination had given hardness values in the neighborhood of 400 Brinell and was weak in impact and fatigue. An attempt was therefore made to produce a weld between the two materials without mixing the melts. Since stainless has a lower heat conductivity it was possible to bring it up to temperature ahead of the low-alloy steel; the latter was at the plastic stage when the weld was made. A micrograph shows an excellent bond is obtained without mixing.

Maximum hardness of the weld was 285 in the low-alloy steel, and 174 in the stainless and the strength of the weld in shear and tension and ductility was much superior to that made by the previous method.

WB (2a)

2b. Non-Ferrous

Indium Plating

A Composite

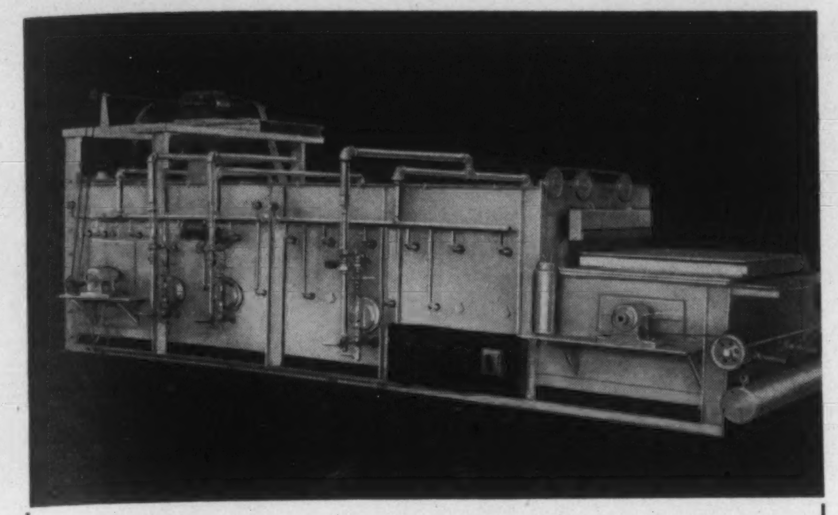
The very rapid drop in the price of indium in recent months [*see our February issue, p. 216*] has tended to expand its use for already-developed applications—such as dental castings and corrosion-resistant indium-plated bearings—and to extend research seeking new values and new uses. Investigation of improved plating baths has also been stimulated, and one such—a sulphate bath as distinct from the conventional cyanide bath—is described below.

Usual Practice

The usual plating practice for producing indium coatings is outlined by J. R. DYER, JR. of Indium Corp. of America ("Indium," *Iron Age*, Vol. 146, Dec. 19, 1940, pp. 35-38). Bearings or other parts to be plated are carefully cleaned, and then plated in an electrolyte containing 4 troy oz. indium (as chloride)/gal., 2 oz. dextrose, and 12 oz. sodium cyanide using currents of 0.1-1.0 ams./in.^{2}

The bath is made by cutting indium metal into small pieces and converting to chloride by dissolving in c.p. hydrochloric acid of 1.16 sp. gr. The excess acid is volatilized, and the indium chloride residue taken up with water. Two oz. of dextrose are dissolved in a little water and added to a solution of 12 oz. of cyanide in a little water. To this mixture the indium chloride is then *carefully* added in small amounts. After standing 48 hrs. the solution is filtered and made up to 1 gallon.

An insoluble anode is used and the resulting deposit is soft, gray and matte-like. The rate of deposition will run about 15 mg./amp.-min., the rate falling as the bath ages. Cyanide content should be held, by



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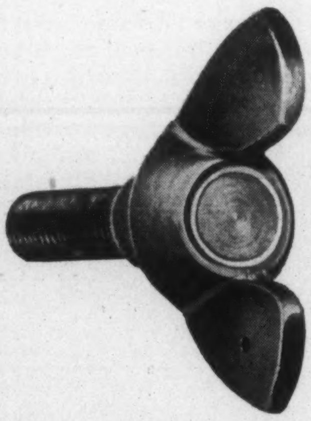
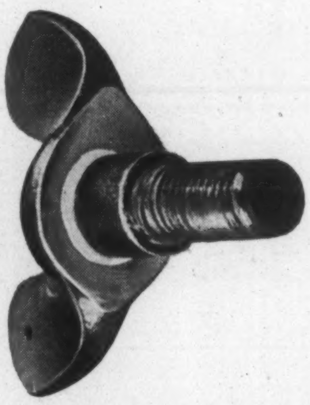


These front and back views show how EASY-FLO has penetrated to every part of the joint.



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additions, above 11 oz./gal. and indium content above 3 oz./gal. The plated parts are rinsed and then heated for 2 hrs. at 340° F. to cause the indium to diffuse into and alloy with the basis metal.

New Sulphate Baths

Claims have been made that baths like the foregoing disintegrate over long periods of time, with the formation of a brown residue high in indium. Sulphate solutions appear to be stable and have therefore been studied by various investigators. [*An indium sulphate process using insoluble anodes and additions of either boric acid or aluminum sulphate was described in our January issue, p. 88; readers should ignore the reference to price in that article, since the figure given there is approximately 2000% too high.*—F.P.P.]

An indium sulphate plating bath, for the application of smooth matte deposits around 0.0001 in. thick is described by HENRY B. LINFORD of American Smelting & Refining Co. ("Indium Plating," *Trans. Electrochem. Soc.*, Vol. 79; Preprint 79-12, 8 pp.). Operation of this bath over long periods of time indicate it to be stable and constant in performance within the pH range of 2.0-2.7. The pH range is maintained by a combination of soluble and insoluble anodes.

Specifically, it is recommended that soluble anodes (indium rod, for example) be used until the decrease in acid concentration causes the pH value to reach about 2.7. At this point insoluble anodes should be applied and their use continued until the pH has returned to about 2.0. Optionally, the electrolyte may be circulated through 2 cells, with soluble anodes in one and insoluble in the other, with the work pro-rated in each cell to maintain a constant pH.

Baths are prepared by dissolving indium metal ribbon in dilute sulphuric acid, filtering, diluting to required amount and adding sodium sulphate. The bath should contain 20 g./l. (2.45 troy oz./gal.) indium, at pH 2.2; and 10 g./l. sodium sulphate. The plating cell should be so equipped as to circulate the electrolyte rapidly—for a 10 liter cell a circulation of 200-400 cc./min. has proved to be satisfactory.

In a typical case—the plating of a cadmium-silver-copper connecting rod bearing of 8.6 in.^{2} area—125 cc. of the above bath was employed to deposit 0.070 g. of indium in 2 min. 44 sec., at a current density of 20 ams./ft.^{2} and 2.0-2.5 volts. Heat treatment of plates of this type to promote diffusion into the base metal is being further investigated by the author. X (2b)

Fusion Welding Aluminum Alloys

"WELDING ALUMINUM AND ITS ALLOYS BY ARC, TORCH AND PRESSURE PROCESSES. A REVIEW OF THE LITERATURE TO JAN. 1940." W. SPRARAGEN & G. E. CLAUSSEN. *Welding J., N. Y.*, Vol. 20, Jan. 1941, pp. 1s-79s. Correlated abstract; 543 references.

The major section-headings of this monumental review include oxyacetylene welding, oxyhydrogen welding, metal-arc welding, atomic hydrogen welding, carbon arc welding, carbon resistor, Arcogen process, capillary brazing, hard-facing, corrosion of aluminum and its alloys, macro- and microstructure, alloys that have been welded and methods of testing.

The outstanding fact about aluminum and aluminum alloy welding is the practical impossibility of attaining in welded joints the high strengths that can be secured in unwelded metal through cold work or heat treatment. The critical factors for aluminum welding are the tendency to oxidize and its hot shortness; a flux is invariably needed to overcome oxidation, and the hot metal should not be subjected to shrinkage and reaction stresses.

Sections of aluminum 0.004 in. thick and greater can be welded with the oxyacetylene torch, but distortion is likely in sizes below 0.079 in. Preheating to 700°-800° F. is required for plates 3/8 in. and over in thickness in order to obtain root penetration and reduce gas consumption in welding.

With the possible exception of high-silicon casting alloys, all aluminum alloys require a flux for oxyacetylene welding. The desirable properties of the flux are effectiveness at temperatures 100°-200° F. below the melting point of the alloy; good dissolving power for aluminum oxide; good spreading power; non-toxicity; stability in the atmosphere; and non-volatility. A film of slag replaces the oxide on the aluminum, and the slag must have a lower surface tension than the oxidized aluminum.

A neutral or slightly reducing flame is recommended and pure aluminum or 5-10% Si alloy rod is generally used. The welding procedure is adjusted to the requirements imposed by thickness of material and other considerations. The welding speed of aluminum and steel are about the same. In order to deposit weld metal of the same composition as the base metal, it may be necessary to have excess magnesium and

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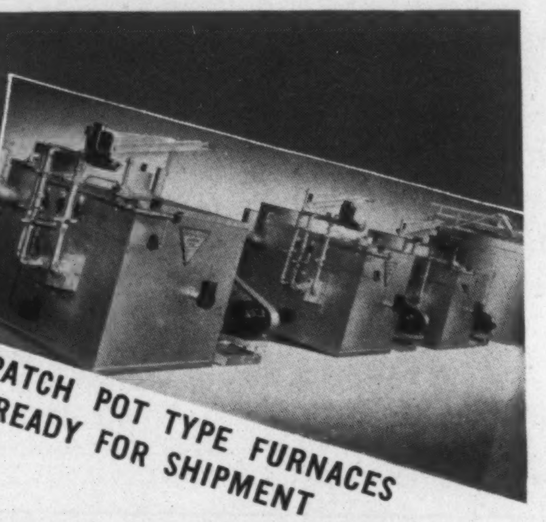
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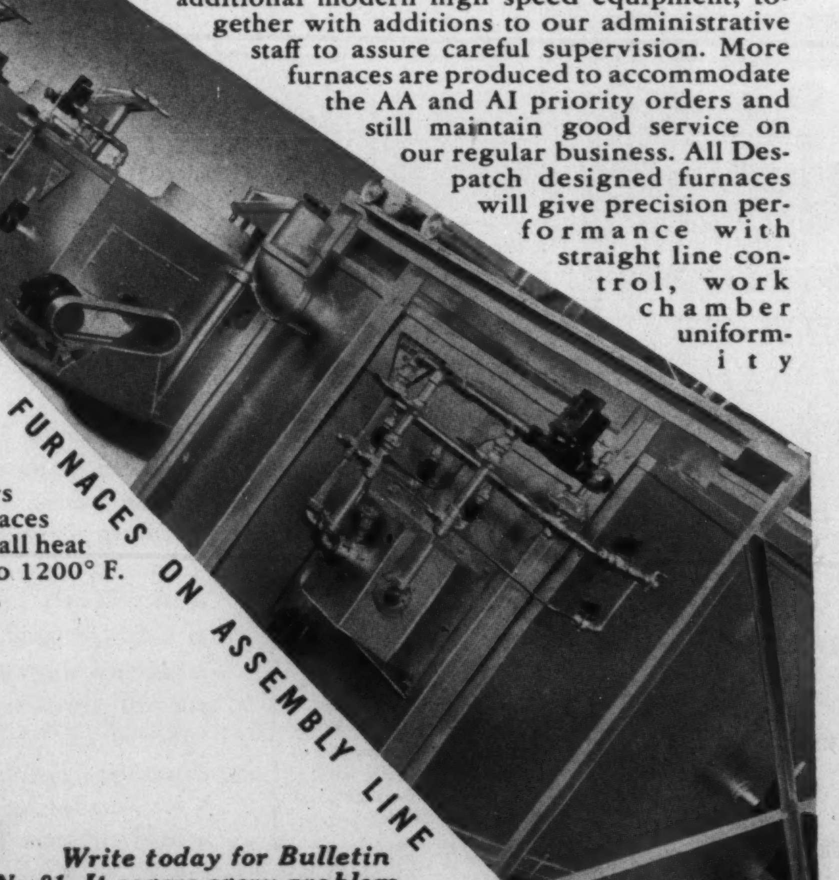
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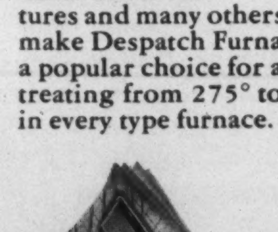
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silicon in the rod. For 13% Si alloys, a loss of 3% Si may occur, but there will be no loss if flux is used.

Hot peening of weld metal at 575°-660° F. is to be recommended since it removes the cast structure, relieves shrinkage stresses, and raises ductility and tensile strength. Peening is usually confined to the soft alloys (2S and 3S, annealed or half-hard state) since the hard or heat-treated alloys crack if severely hammered.

Tensile tests on oxyacetylene welded material indicate that for aluminum the strength is the same as soft wrought aluminum, because fracture always occurs in the softened zone. All aluminum weld metal has the same elongation as the wrought, annealed material. Aluminum-manganese alloys have higher strength than pure aluminum, but fracture occurs in the softened zone unless an aluminum rod is used for the weld. Aluminum-copper alloy welds have about half the strength of the heat-treated base metal, but heavy hot and cold peening plus complete heat treatment give properties similar to those of the parent metal. Duralumin welds have 50-70% of the strength of the heat-treated base and low ductility; this can be raised to 85-95% by heat treatment.

Aluminum-magnesium (2-2.5% Mg) welds have 80-100% of the annealed-base-metal strength, and 75% of the strength of the cold-rolled base. Elongation is 50% or more of that of the annealed base. Aluminum-magnesium-silicon weld tensile strength is equal to that of the annealed base metal; the welds have only 40% of the yield strength of the heat-treated base but heat-treated welds have properties similar to the base-metal in the same condition. Aluminum-silicon alloys with 13% Si have the same strength of weld as the softest zone near the weld. Notch impact tests on welds generally give low values but fatigue tests report good values for the 99.4% pure aluminum and for the 10.5% Si alloy.

Arc welding is successful with covered electrodes. However, the thinnest material that can be butt-welded is 0.039 in.; the minimum for fillet welds is 1/8 in. since the arc is difficult to control and burning-through cannot be avoided in thinner sheets. Thick plate and long complicated welds may require preheating, the former to maintain a puddle, the latter to prevent distortion.

Weld deposits of the same composition as the base metal are desirable for maximum corrosion resistance, but 5% Si alloy electrodes are favored for any alloy because of excellent fluidity. Arc welding may be 3 times as fast as arc welding of steel, but too rapid advance produces poor penetration. The mechanical properties of arc-welded aluminum and its alloys are excellent. WB (2b)

Heat Treating Clad Aluminum Alloys

THE PROGRESS OF DIFFUSION IN CLAD ALUMINUM-COPPER-MAGNESIUM ALLOYS ("Zur Kenntnis des Diffusionsverlaufes in Al-Cu-Mg-Verbundwerkstoffen—Deckschichten aus Reinstaluminium, Reinaluminium, und Al-Mg-Si-Legierung") H. J. SEEMANN & M. DUDEK. *Aluminium,* Vol. 22, Oct. 1940, pp. 521-524. Investigation.

In the course of the manufacture and heat treatment of duralumin-type alloys clad with high-purity aluminum, commercial-purity aluminum or aluminum-manganese-magnesium-silicon alloy (1 Mn, 0.5 Mg, 0.25 Si, 0.2 Fe) diffusion of alloying elements from the core material into the coating occurs. The effects of such diffusion vary according to the nature of the coating layer. The thickness of the clad layers tested was 4-6% of the total thickness, and the progress of diffusion was investigated at different temperatures with different annealing times.

It was found that copper diffusion into the commercially pure aluminum and, more pronouncedly, in the highly pure aluminum occurs preferentially at the grain boundaries, while with the alloy cladding the diffusion is characterized by a common diffusion front for grain boundary and grain interior. Curves could be established for the depth of penetration of copper as a function of the duration of annealing at a constant temperature and also as function of the annealing temperature for constant annealing times. Such curves can be used as a basis for determining the best heat treatment to obtain a definite condition of diffusion.

With regard to corrosion resistance of the various layers, the faster grain boundary diffusion and consequent formation of "copper channels" in the two types of aluminum cladding can hardly have a favorable effect, especially in the age-hardened state. Cracking and fracture of the layers have often been observed to be typical of this type of cladding and such defects can be traced to the grain boundaries, where copper has accumulated by diffusion. Where these cracks had penetrated to the core material, inter-crystalline corrosion could always be observed in the latter after extended exposure to corrosive action. This harmful effect of copper diffusion was not observed in clad layers of the aluminum-manganese-magnesium-silicon alloy. Ha (2b)

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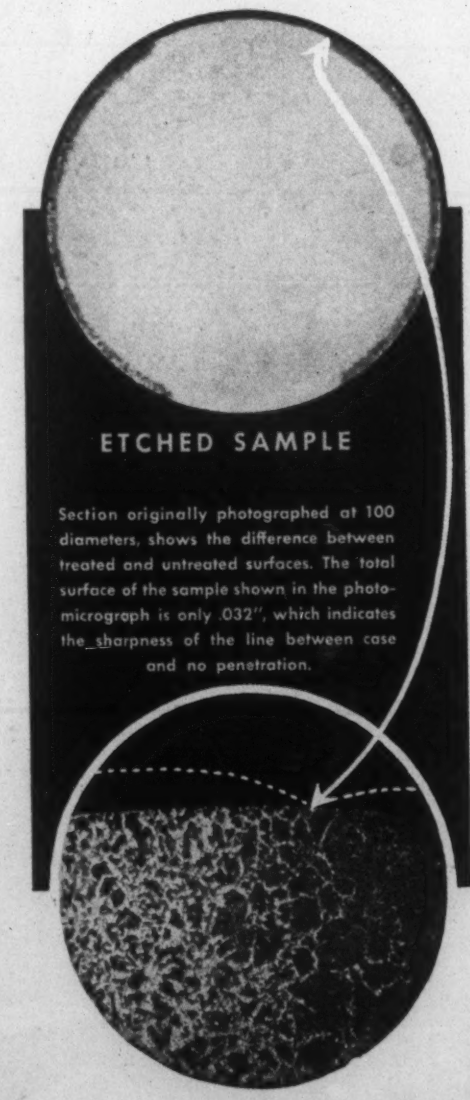

ETCHED SAMPLE

Section originally photographed at 100 diameters, shows the difference between treated and untreated surfaces. The total surface of the sample shown in the photomicrograph is only .032", which indicates the sharpness of the line between case and no penetration.

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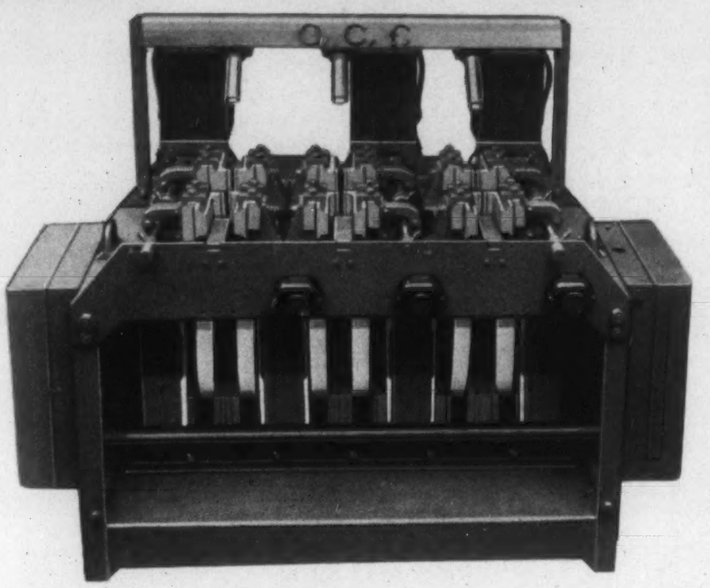

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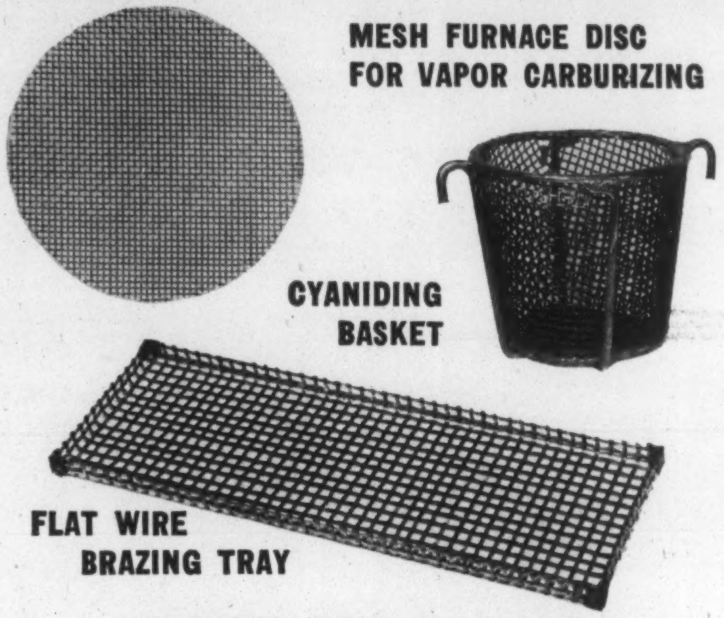

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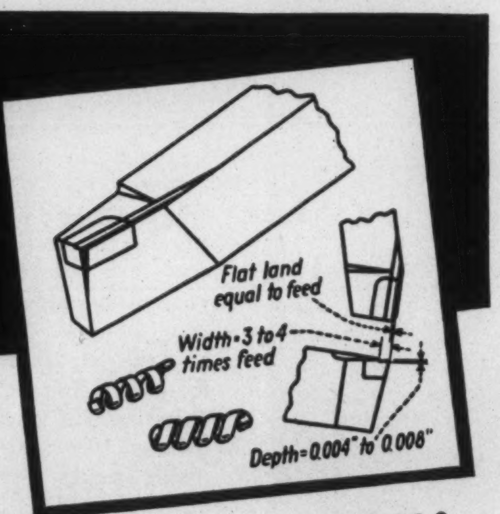

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Lead Anodes for Zinc Plating

"Investigation of Lead Anodes in the Electrolysis of Zinc Sulfate Solutions." A. E. Koenig (Montana School of Mines), J. U. MacEwan (McGill Univ.) & E. C. Larsen (Univ. Wisconsin)) *Trans. Electrochem. Soc.*, Vol. 79, 1941; Preprint No. 8, 12 pp. Research.

In the electrodeposition of zinc, pure solutions are necessary for securing satisfactory deposits. Since insoluble anodes, such as lead, may be used, it was of interest to study the effect of impurities in the bath and in the anodes on the electrochemical behavior of the anodes and on the quality of the cathode deposit.

The bath contained zinc (as sulphate), 40 g./l.; and sulphuric acid, 105 g./l. The presence of the following elements in quantities of 0.001-0.05 g./l. in the electrolyte did not materially affect the potential of the lead anode: sodium, magnesium, manganese, nickel and iron. Cobalt, however, caused the anode potential to be about 0.12 volt less noble, and both cobalt and nickel caused a re-solution of the zinc deposit on the cathode. In the presence of cobalt, the lead anode did not become covered by a coating of PbO_2.

The lead alloys employed as anodes were binary alloys of lead with bismuth, magnesium, arsenic, cadmium, antimony, tin and silver. Small quantities of these metals were dissolved from the anode during electrolysis and with the exception of magnesium, adversely affected the deposit of zinc. Lead dioxide did not form on the lead-silver alloy anode.

In general, lead to the extent of several hundredths of a percent was found in the zinc deposit. This was shown to be due to the occlusion of PbO_2, which was formed at the anode and became suspended in the bath. The amount of lead impurity in the cathode deposit could be reduced by bagging the anode, or by preventing the formation of PbO_2 through the use of the lead-silver alloy anode, or by adding a cobalt salt to the electrolyte. AB (2b)

Which Process for Anodizing?

"Formation of Anodic Coatings on Aluminum." J. D. Edwards & Fred Keller (Aluminum Research Labs.) *Trans. Electrochem. Soc.*, Vol. 79, 1941, Preprint 79-11, 8 pp. Research.

The coatings formed on aluminum by anodic oxidation in dilute solutions of sulphuric, oxalic, chromic and boric acids are, as far as can be determined by X-ray and electron diffraction methods, amorphous. They are comprised chiefly of aluminum oxide but also contain substances adsorbed from the electrolyte.

Coatings formed in boric acid electrolyte are substantially impervious and non-adsorptive; whereas, those formed in sulphuric, oxalic and chromic acid electrolytes are porous and adsorptive. The porosity in the latter type of coating is attributed to the solvent action of the electrolyte and this porosity is thought to be responsible for the adsorptive characteristics of these coatings. The presence of pores permits the continuous passage of current; consequently, coatings made in these electrolytes can be produced with a substantial thickness.

For the elecrtolytes investigated, the anodic oxidation process is about 100% efficient as far as the conversion of aluminum to oxide is concerned. As a result of the solvent action of the more powerful electrolytes on the oxide, the apparent current efficiency in terms of oxide remaining as coating was shown to be as low as 50% or less.

Thus, experiments with coatings formed in boric acid-borax electrolyte (90 g./l. boric acid and 2 g./l. borax) at 230 v. and at a temperature of 95° C. showed a current efficiency of 96.6% in the formation of the coating. However, alumina slowly accumulates even in boric acid electrolytes. The current density with the chromic acid electrolyte is only about one-quarter that used with sulphuric acid and oxalic acid, and the coatings made in chromic acid electrolyte are usually quite thin, 0.0001 in. $(2.5\ \mu)$ or less in thickness.

The fact that the oxide occupies a larger volume than the metal from which it is formed is demonstrated visually. This increase in thickness resulting from the application of an anodic coating must be considered where close fits are required between coated parts. The size of the increase should vary, depending upon the amount of coating lost through the solvent action of the electrolyte. In one case, a piece of aluminum foil 1 mil in thickness was completely oxidized in sulphuric acid electrolyte and the foil increased in thickness by an amount equal to about one-third the thickness of the coating formed. Coatings produced with sulphuric acid electrolyte are usually several times as thick as those obtained when a chromic acid electrolyte is employed. FPP (2b)

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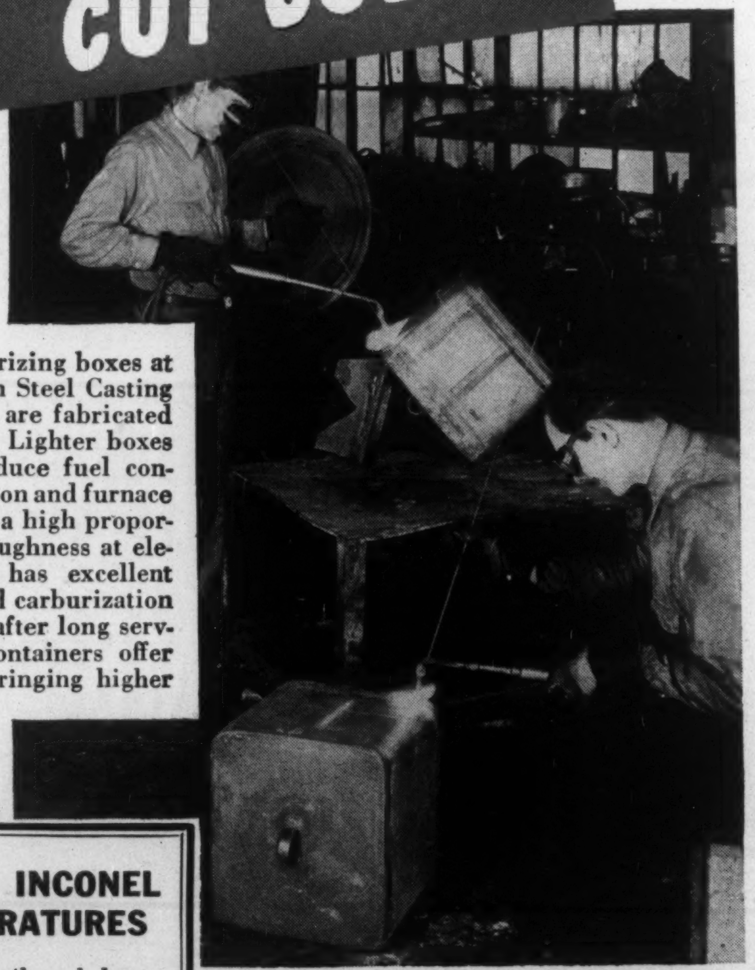

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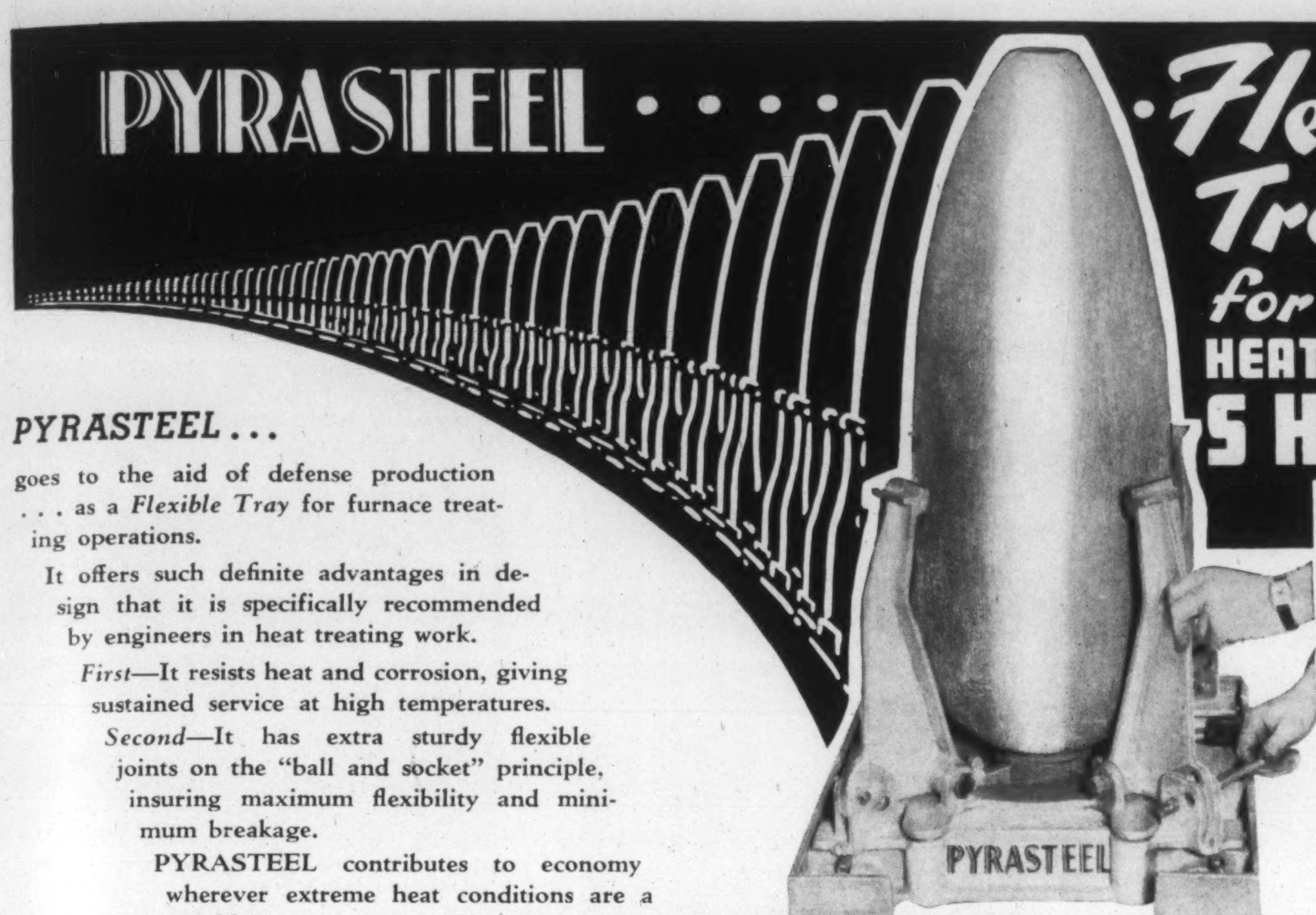

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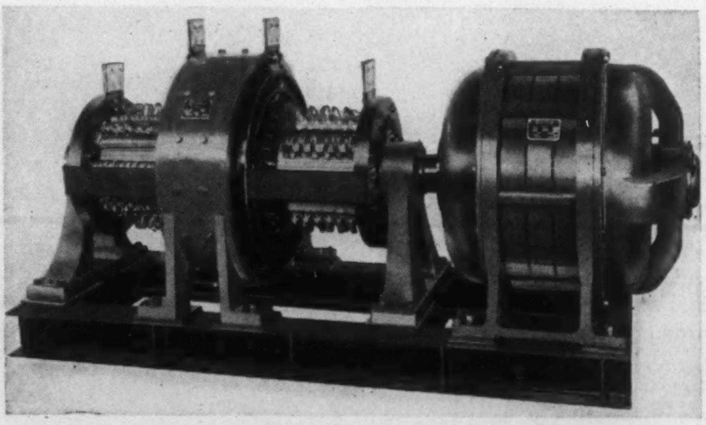

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Aircraft Metals at Low Temperature

"Effect of Low Temperatures on the Properties of Aircraft Metals." Samuel J. Rosenberg. *Journal Res. National Bur. Standards,* Vol. 25, Dec. 1940, pp. 673-701. Investigation.

The effect of subzero temperatures down to —110° F. on the tensile properties, hardness, and impact resistance of metals commonly used in aircraft construction was determined. The materials were divided into 3 general groups: (1) ferritic steels, (2) austenitic stainless steels and nickel alloys, and (3) light metal alloys (both aluminum- and magnesium-base).

In making the tensile tests at —110° F. an insulated container was screwed on the bottom of the specimen directly above the lower adapter. This container was filled with cracked carbon dioxide and a 50-50 mixture of carbon tetrachloride and chloroform. An especially designed extensometer using Ames dials reading directly to 0.001 in. was used in obtaining the strain measurements. Hardness tests were made with a Rockwell machine.

An insulated container, made integral with an anvil which fitted into the elevating screw of the machine, was used to hold the refrigerating mixture. In making the impact tests, a modified Charpy V-notch specimen was used. The specimens were placed in an insulated container holding the cooling bath, held at temperature for at least 30 min., and then quickly transferred to the impact machine and broken.

In the ferritic group the following materials were studied: SAE 1045, 1095, 2330, X4130, 6130, chromium-nickel-molybdenum steel, high-chromium low-nickel steel. In the austenitic group the following alloys were tested; 18-8, 18-8 with titanium, 18-8 with columbium, 18-8 with molybdenum, K-Monel, Monel, nickel, Inconel. In the light metal group the following alloys were tested: 3S, 17ST, 17SRT, 24ST, 24SRT, 25ST, 25SRT, 27ST, 52S, 195-T4, 220-T4, 355-T4.

The tensile properties and the hardness of all materials were generally improved at low temperatures. The resistance to impact of the ferritic steels decreased generally as the test temperature was lowered, the rate and nature of the decrease being dependent on the type of steel and its treatment. The impact resistance of the austenitic stainless steels and the nickel alloys was not deleteriously affected and they were considered best adapted for service at low temperatures.

The impact resistance of the aluminum-base alloys was not decreased; the impact resistance of the wrought magnesium-base alloys was adversely affected by the low temperatures, while that of the cast magnesium-base alloys was not. These last-named materials were, however, extremely brittle—even at room temperature.

WAT (3)

3a. Ferrous

Strong Non-Magnetic Steel

Non-Magnetic Structural Steel with 17 to 18% Mn ("Unmagnetische Baustähle mit 17 bis 18% Mangan") G. Riedrich. *Stahl u. Eisen,* Vol. 60, Sept. 12, 1940, pp. 815-818. Original research.

The electrical manufacturing industry requires a strong non-magnetic structural steel for many types of electric machines. Formerly austenitic steels with 0.5% C and 25% Ni or 0.5% C, 4-10% Mn and 8-16% Ni were used. Recently higher manganese steels have been substituted for the manganese-nickel steels.

The austenitic manganese steel with 1-1.4% C and 12-15% Mn has the drawback that it is very hard to machine. However, the machinability is greatly improved by lowering the carbon. The carbon can be brought down to as low as 0.3% if the other austenite stabilizing elements are raised. About 8% Cr as well as 2.5% Si injured the machinability, but 1.5% Ni and 0.05% S improved it. Adding about 0.1% N_2 raised the yield strength.

It was concluded that a steel with 0.3% C, 17% Mn, and 1.5% Ni gave as good mechanical properties as the nickel or nickel-manganese austenitic steels, and even better machinability. SE (3a)

Age-Hardenable Hardfacing Alloys

Precipitation-Hardening Alloys as Wear-Resistant Build-Up Welding Materials ("Aushärtbare Legierungen als verschleissfeste Aufschweisswerkstoffe") P. Ehlers. *Autogene Metallbearbeit.,* Vol. 33, Dce. 1, 1940, pp. 301-304. Descriptive.

Hardfaced layers of great hardness, above 65 Rockwell C, are usually cobalt-iron base alloys with 4-5% C; these are often difficult to weld-on and tend to crack. New alloys for this purpose have been developed of lower carbon content but equal hardness, the hardness being obtained by precipitation hardening. The precipitation is produced by heat treatment after the hardfacing operation.

Iron-nickel and iron-cobalt alloys with beryllium and carbon (1.2-3.5% C) have given good results, *e.g.* a nickel-base alloy with 15% Cr, 15 Fe, 2 Mn, 7 Mo and 0.6 Be, whose cold-rolled hardness of 320 Brinell could be increased to 450 Brinell by precipitation-hardening. The highest hardness was obtained in an alloy of 34% Co, 50 Fe, 15 Cr and 1 Be, which after quenching from 1920° F. had a hardness of 225 Brinell, after cold-rolling 470 Brinell, and after precipitation-hardening 680-700 Brinell (60-62 Rockwell C).

Commercial alloys of this type called "Gridur E" with under 3.5% C can be hardened, without previous quenching, by aging at about 1475° F. and give a hardness of 65-67 Rockwell C. Ha (3a)

Iron Castings at High Temperatures

"Use of Cast Iron Apparatus at High Temperatures." G. N. Troitskii. *Metallurg,* Vol. 15, Aug. 1940, pp. 50-53. In Russian. Experimental.

Studies were conducted of seven iron castings that had been used for extended periods at 380° and 700° F. It was found that high-silicon high-carbon cast iron may "grow" even at 400° F. Although growth of 1-2% may not be dangerous in itself, if internal or external stresses, or both together, should be co-existent, it is inadvisable to use any weak open-grained iron for 400° F. service.

However, strong close-grained iron of good strength in actual castings sections is safe for usage at 660°-700° F., if proper design is employed and internal stresses are absent or removed. The author states that with 1.4-1.7% Si and 0.15-0.20 Cr no growth is observed at 600° F. [*The practical significance of the author's findings is that limitations on temperature of usage of cast irons depends on the quality of the metal in the castings. Use of the A.S.T.M. A48-36 specification, which takes into account both strength and section effects, or specification of definite classes for definite structures (as in some A.S.A. standards) may well allow safe usage at temperatures beyond the 450° F. of the A.S.M.E. Boiler Code and other ratings.* —J.W.B.] BZK (3a)

Cast Crankshafts—Fatigue Behavior

Behavior of Some Crankshaft Casting Materials under Fatigue Stressing, in Bending and Torsion ("Verhalten einiger Kurbelwellen-Gusswerkstoffe bei Dauerbeanspruchung bei Biegung und Verdrehung") H. Cornelius. *Giesserei,* Vol. 27, Dec. 13, 1940, pp. 491-499. Investigation.

For evaluating the suitability of casting materials to be used for crankshafts, notch sensitivity is considered to be more important than bending and particularly torsion fatigue strength. Four materials, malleable iron, alloy gray iron, high-carbon

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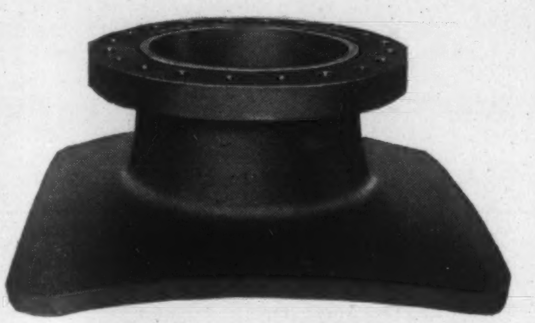

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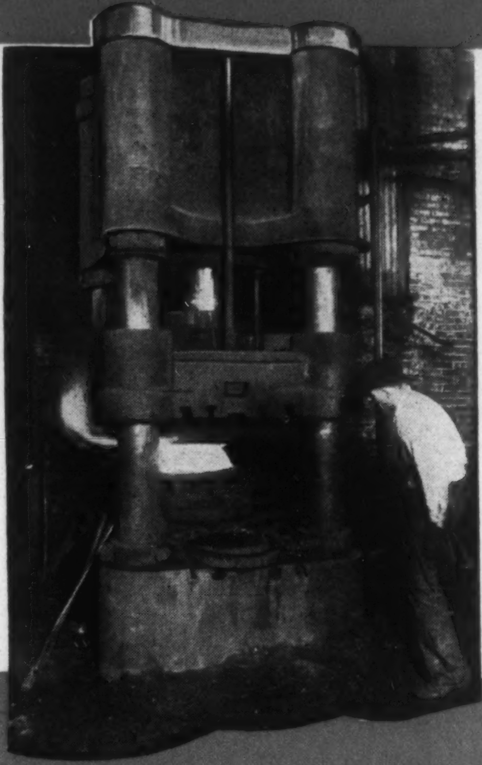

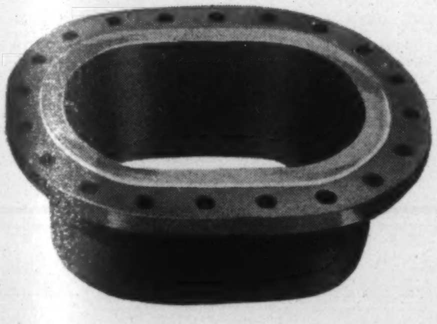

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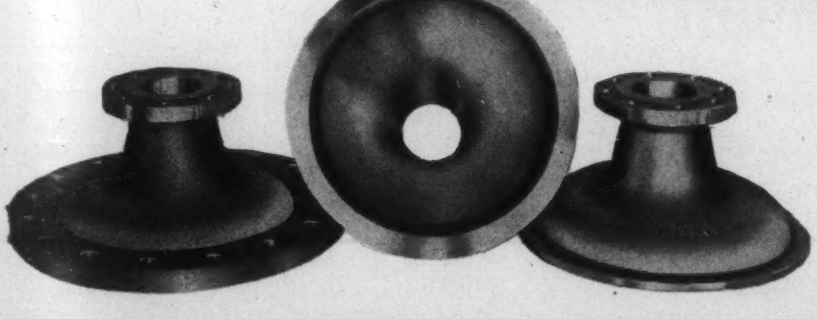

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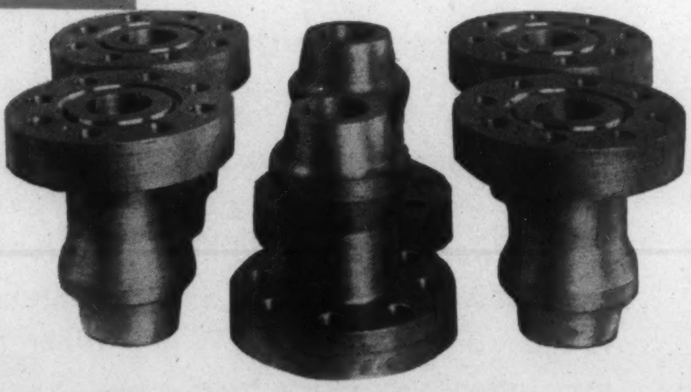

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steel, and rolled steel were tested for torsion fatigue under 3000 load reversal per min. up to a maximum of 10 million reversals, with and without notch.

The alloy iron and malleable castings, with their graphite and temper-carbon constituents, showed high bending fatigue strength of notched specimens in relation to their tensile strength; this is explained primarily by their considerably lower notch-sensitivity as compared with rolled steel. Transversely drilled samples of high-strength castings also had high torsion fatigue strength in relation to tensile strength, and this is explained as due to the high ratio of torsion fatigue strength to tensile strength of smooth specimens.

The fatigue strengths of high-grade hardenable steels are not reached by the cast irons, because of the high tensile strength obtainable by hardening the steels. Soft iron has a high ratio of bending fatigue strength to tensile strength and a lower notch-sensitivity in fatigue bending. The values of bending fatigue strength of smooth and notched samples of soft iron were higher than the corresponding figures for malleable castings of equal static strength. Ha (3a)

3b. Non-Ferrous

Aircraft Design for Magnesium

"PRESENT STATUS OF ULTRA-LIGHT ALLOYS IN AIRCRAFT CONSTRUCTION." *Light Metals,* Vol. 3, Feb. 1941, pp. 3-6. Review.

Improved casting and working techniques and effective protection against corrosion have been responsible for the greatly increased use of magnesium alloys in aircraft in recent years. The notch sensitivity of magnesium alloys has been largely minimized by the use of proper design.

While magnesium alloys were originally used only in large, unstressed parts such as crankcases, present day techniques permit their use in many moderately-stressed parts such as certain engine components, airframe structure, landing gears, etc. Such use has achieved a noteworthy reduction in total weight. In the "Master" fighter trainer, there are 360 separate magnesium alloy castings, of which 235 are different. In the German "Arado A.R. 79" trainer, the monocoque fuselage, cowlings, flaps, etc. are constructed of magnesium alloy sheet.

One of the most readily defined trends is the use of magnesium castings in engine construction. Some of these are crankcase sections, super-charger casings and housings, intake manifolds, thrust bearings, accessory and starter drive housings, camshaft covers and housings, and pump bodies. A few of these alloys provide satisfactory bearing surfaces: For example, the sliding member in nickel-chromium steel, of an internally sprung landing gear, bears on the magnesium alloy casting rather than on the phosphor bronze sleeve originally used.

The undercarriage provides applications for magnesium alloy forgings, particularly in members subject to oil under pressure such as hydraulic jacks and automatic cut outs. Many German machines are equipped with forged magnesium alloy engine supports. Some authorities believe that magnesium alloys will be eventually used for engine pistons. The magnesium alloy airscrew is in commercial production in England. The early failures of magnesium alloy airscrews have been overcome by suitable design, forging technique and corrosion protection.

Magnesium alloy sheet and extrusions have been almost entirely confined to unstressed or lightly stressed applications. Outstanding exceptions to this are the use of magnesium alloy extrusions for the main spars of the flying boat DO-X, and magnesium alloy sheet in the Arado aircraft previously mentioned. Sheet is ordinarily used in oil and fuel tanks, cowlings, cabin linings and partitions, pressed parts for seats, etc. Where strength is of secondary importance, the saving in weight in replacing aluminum alloy may be as much as 33%. It seems quite probable that magnesium alloy sheet will be successfully used for wing and fuselage coverings, even in ultra high speed aircraft. The use of thicker sheet would make possible accurate profiles free from local irregularities.

The amount of weight that could be saved in this manner is still a matter of conjecture. In a pure monocoque, the use of magnesium alloy in place of aluminum would result in a weight saving of 26% in flat sheet and 20% in curved sheet. Theoretical analyses carried out on sheet stringer combinations in aluminum and magnesium alloys indicate that for sections of equal weight, the load carried by the magnesium unit would be some 32% greater than that carried by the aluminum section. While these figures were obtained from theoretical considerations and are not necessarily an accurate guide to practical possibilities, they do justify additional work along these lines.

Aluminum pigments have been found to provide adequate corrosion protection in many atmospheres. Paints with aluminum pigments are used over magnesium alloy

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treated with either the chrome-pickle or phosphoric acid processes. While magnesium alloys thus protected are suitable for use in marine atmospheres, frequent actual contact with sea water must be avoided.
AUS (3b)

Aluminum Alloy Permanent-Mold Castings

"Gravity Die-Castings in High-Strength Aluminum Alloy." *Foundry Trade J.*, Vol. 64, Jan. 2, 1941, pp. 3, 4, 6. Descriptive.

The advantages accruing from the use of permanent-mold castings in aluminum alloy have been emphasized in an earlier article (*Foundry Trade J.*, Vol. 63, Nov. 28, 1940, p. 348) on motor-vehicle construction. Generally speaking, parts required in lots of 1000 or more per year will justify consideration of permanent-mold castings.

For such components as radiator and water-pump parts, gear-boxes, housings and manifolds, high-silicon alloys have been widely used. For pistons, these alloys or more complex materials such as "Y" alloy are used. In all cases the design requirements are complicated by the need for a combination of castability, good tensile strength, stiffness, resistance to momentary overloading, corrosion-resistance, etc.

The properties desired are claimed to have been combined in a new casting alloy, known as N.A. 226, containing 4-5% Cu, 0.9 max. Si, 0.7 max. Fe, and 0.25 max. Ti, with impurities (Mg, Mn, Zn, etc.) less than 0.2. The alloy is heat-treatable, and a wide range of mechanical properties can be obtained by varying the heat treatment. The 0.1% proof stress reached for this alloy was as high as 50,000 lbs./in.^{2}, with elongation of 5% in 2 in.

Parts that are normally made of forgings, involving costly dies, or built up from sheet and extruded sections with considerable expense in machining and welding, may be made of permanent-mold castings in this high-strength aluminum alloy. The material meets a wide range of requirements involving strength, stiffness, shock-resistance, etc. Its machining qualities are excellent, and its good natural resistance to corrosion can be improved by anodizing.

However, this alloy does not flow so readily as the silicon-bearing alloys or "Y" alloy, and should not be used for castings of widely-varying thickness or for those with sectional thicknesses less than 3/16 in. Other points requiring consideration are shrinkage on solidification and hot-shortness. Adequate radii should be provided, both in order that the metal may flow into the corners, and also to facilitate extraction from the die. These considerations all lead to complexity of the die design, so that not in all cases are parts practicable for production in this alloy.
AIK (3b)

Silver in Battery Lead Alloys

"The Effect of Silver (0.05 to 0.15 per cent) on Some Properties and the Performance of Antimonial Lead Storage Battery Grids." Colin G. Fink & A. J. Dornblatt. *Trans. Electrochem.* Soc., Vol. 79; Preprint 79-10, 37 pp. Research.

Although the interesting corrosion-resistant properties of lead anodes containing silver have been known for some time, no previous study of the effect of silver present in storage battery grid metal has been published. The study is of interest because

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ordinary antimonial lead, although involving less corrosion of the positive grids and lower charging potential, is subject to more rapid sulphation, tends to pit, and has a higher electrical resistance than pure lead. The addition of silver is an attempt to overcome some of these deficiencies without sacrificing the beneficial effects of antimony—chiefly improved castability, stiffness, and tensile strength—in the grid alloy.

Sixteen 6-cell storage batteries, representing 16 different grid compositions, were commercially assembled for tests of battery performance, capacity, retention of charge on open circuit and battery life. The grid alloys tested contained 4-12% Sb, and the amounts of silver added ranged from 0.05 to 0.15% Ag.

About 0.1% Ag added to the antimonial lead inhibits anodic corrosion, increases battery life and increases the amount of charge retained on open circuit. Practically complete corrosion inhibiting is achieved by 0.10-0.15% Ag. Life was prolonged about 4%. Batteries whose grids contain silver are less likely to overheat on overcharge.

Chill-cast antimonial-lead grid alloys containing 4.8% Sb can be heat-treated with marked improvement in strength and some improvement in conductivity; the addition of 0.05-0.10% Ag increases the maximum strength obtainable by about 20%. The highest strength is reached in the alloys of lowest (4% Sb) antimony content. In the absence of heat treatment, up to 0.15% Ag has little effect on the strength of these alloys.

Thus, some of the deficiencies of the present antimonial-lead storage battery may be overcome by (a) adding 0.10% Ag to the present grid alloy used for the positive plate, or (b) adding 0.10% Ag to both positive and negative plates of the 4% Sb or 6% Sb alloy and using the grids in the heat-treated conditions. To do this increases the cost but slightly. In the case of the heat-treated alloy, the cost is not increased and may even be slightly reduced by replacing 4-8% Sb with 0.10% Ag.

And incidentally, the general adoption of the low-silver, low-antimony lead alloy for battery grids could go a long way toward solving the strategic problem of antimony supply. It would also be a step in the direction of absorbing some of our huge surplus of silver. FPP (3b)

Pitting of Non-Ferrous Alloys

"INFLUENCE OF STRESS ON THE CORROSION PITTING OF ALUMINUM BRONZE AND MONEL METAL IN WATER." DUNLAP J. MCADAM, JR. & GLENN W. GEIL. *Journal Res. National Bur. Standards,* Vol. 26, Feb. 1941, pp. 135-160. Research.

Corrosion pits in aluminum bronze, unlike the pits in steels, generally are not free to assume a roughly hemispherical form but are confined between crystallites of the alpha phase. Pits in Monel metal are more like those in steel. Pits in aluminum bronze and Monel metal are much smaller than those in steel.

Cyclic stress tends to increase both the size and sharpness of the pits. The effective stress concentration that causes the lowering of the fatigue limit depends on both the size and the sharpness. A sufficiently high combination of stress, cycle frequency, and corrosion time causes fissures to develop from blunt pits. Fissures in the aluminum bronze generally are oblique, whereas fissures in steel and Monel metal tend to be perpendicular to the direction of the principal tensile stress.

The curves of decrease of the fatigue limit with corrosion time are of the accelerated-damage type. Such curves are obtained when the corrosion rate is anodically controlled. With these two alloys, therefore, the pits in a specimen have a wider range of size and sharpness than the pits formed under cathodic-control, as in steels. The pit that caused the lowering of the fatigue limit may have been much larger and sharper than the pits found in the sectional views. The damage may then be greater than the sectional views would indicate. Many of the sectional views, however, give good correlation with the resultant fatigue limits.

Steady stress tends to accelerate corrosion of aluminum bronze but has little apparent effect on the corrosion pitting of Monel metal. WAT (3b)

Service-Softening of Copper Wire

"THE EFFECT OF PROLONGED HEATING AT 80° C. ON COPPER WIRE." E. VOCE *J. Inst. Metals,* Adv. Copy No. 889, 1941, 7 pp. Research

Three different brands of electrolytic copper, each in the form of hard-drawn wire of two different diameters, were heated at 80° C. for periods up to 18 months. The degree of softening of the wires as determined by the tensile test was not appreciable with some of the materials and in no case was it complete.

The results show that the softening of hard-drawn high-conductivity copper wire on long heating at 80° C. is less than was asserted by von Zeerleder and Bourgeois. Analyses of the wires are given, and indicate that those with the most silver softened the less. JLG (3b)

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Photomicrographic Exposure Meter

"AN EXPOSURE METER FOR PHOTOMICROGRAPHY." H. S. JERABEK & W. W. WOLF. *Metal Progress,* Vol. 39, Mar. 1941, pp. 330-332. Descriptive.

Several methods of estimating exposure time in photomicrography have been proposed—most of them too cumbersome for wide application. A simple method, involving the adaptation of an extinction type of exposure meter popular with amateur photographers, is described.

The "Instoscope", an inexpensive cylinder-type meter capable of measuring the very low light intensities used in photomicrography, was the instrument employed. The intensity of the light reaching the ocular of the microscope is measured by holding the meter (by an adapter) in the position normally occupied by the eyepiece. Such an adapter can be made of darkened cardboard or metal tubing.

Calibrated scales are presented in the article, to provide for specific conditions of film speed, filter factors, objective aperture, and magnification. The scales are carefully worked-out modifications of the calculator chart data on the instrument as-purchased.

In using the meter, after the microscope has been focused, the field selected and iris diaphragms adjusted, the visual eyepiece is replaced by the exposure meter. A reading is taken for the light intensity with the color filter in place. About 15 sec. is allowed for the eye to become adjusted to the dim light before the reading is made. The faintest letter that can be read on the step scale is used as the light intensity value in computing exposure by means of the calculator chart. (4)

Soaking Pit Control

"SOAKING PIT CONTROL." M. J. BOHO (Hagan Corp.) *Iron & Steel Engr.,* Vol. 18, Jan. 1941, pp. 34-42; discussion. pp. 42-43, 53. Descriptive Review.

Present-day pit designs produce more and better-heated ingots at lower cost. Surface imperfections in slabs and blooms, attributable to improper ingot heating, can be practically eliminated because of the more precise control of furnace temperature and atmosphere available with the new pits. Output per unit of floor space is increased by the more efficient applications of heat to the ingot and by the reduction in lost heating time caused by excessive bottom making and refractory maintenance. Cost per ton of ingots is dropped due to the lowered fuel consumption and the decreased labor cost per ton of ingots heated.

While different in construction and method of operation, all of the new pits have one thing in common—automatic control as an intergral part of the installation. The functions of the automatic control apparatus follow in principle the operating methods used by the heater when operating the pit under manual control, with the exception that the judgment of pit temperature, atmosphere and pit pressure is based on direct measurement.

The heater operating a soaking pit is continuously interested in 3 factors other than the physical handling of the steel ingot; these are rate of heat input, fuel-air ratio, and rate of flue gas removal or furnace pressure. The pit may be charged with ingots taken from storage and cold throughout, or it may receive ingots immediately after stripping which, while having a solid shell, are still molten within. In either case, a correctly heated ingot of proper rolling temperature, uniform throughout its entire mass, free from washing, and having the right kind and thickness of surface scale, must be produced.

Heat input to the modern soaking pit should depend entirely on the ability of the steel charge to absorb heat. The method in present use for heat input control involves the measurement of temperature at some particular point within the pit. In some cases, this is the temperature of a thermocouple in the cover, in the sidewall, or in the flue gases leaving the pit; or, again, it may be a combination of two of the above. In any case, the temperature of the control point is not the temperature of the steel ingot, but merely relative to combined pit and ingot temperature. This relationship is determinable by test.

The fact that the control point is up to temperature, even after calibration, is not indication enough of itself that the steel is properly heated. Another factor must be

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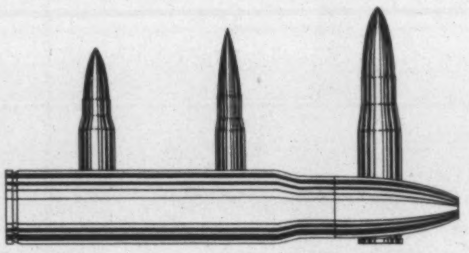

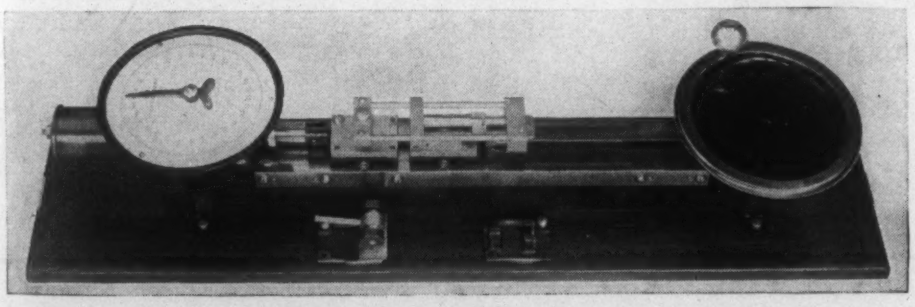

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considered—the actual flow of heat to the pit. The rate of heat input to the modern pit can be controlled by primary variation of the fuel flow or the air flow, since fuel-air ratio regulation is always part of the control equipment.

If the heat input control, or as it is more commonly called, the temperature control, varies the rate of fuel input, the ratio control proportions air flow. If the temperature control varies air flow, the fuel-air ratio regulator adjusts the fuel. For variable Btu. fuels, the second method is to be preferred as changes in calorific value are felt immediately by the Btu. correcting mechanism and compensated by a variation in flow, even before a temperature change takes place. Control of heat input by variation of air flow has another advantage; on loss of air, due to fan failure or some other cause, fuel is automatically reduced in proportion by the fuel-air ratio control, thereby lessening the danger of explosion.

An important feature in fuel-air ratio control for soaking pits is a means for adjustment to slightly increase the ratio of air to fuel as firing rate is decreased. This becomes more important as the pits become larger and more heavily insulated, and the spread between maximum firing rate and that necessary to supply radiation losses becomes greater. An increase in excess air is helpful, since it tends to increase the volume of the products of combustion and to lower their temperature, with the result that heat can be transmitted by conduction to all parts of the pit.

The pressure within the pit chamber is an indication of the balance between the rate of air and fuel input and the rate of gas removal. With the pit in operation, an unvarying furnace pressure indicates that flue gases are removed as fast as they are formed. An increasing pressure shows too slow a rate, and a decreasing pressure, too fast a rate of removal. A regulating device designed to feel this pressure can be arranged to open the outlet damper if the pressure increases and to close the damper if the furnace pressure tends to drop. By properly operating the damper, the opening can be made exactly proportional to the requirements, and the furnace pressure can be kept at a constant value at all times.

The point from which to control furnace pressure, for much the same reason as with temperature control, depends entirely on the pit design and the method of firing. It is conceivable that it might, in some cases, be desirable to vary the furnace pressure in accordance with firing rate for better application of heat to the ingots.

As a matter of fact, one manufacturer of soaking pits has made several installations where no attempt is made to maintain a constant pit pressure. The operation of the outlet damper is coordinated with the firing rate in such a manner as to produce the desired heating effect on all of the ingots in the pit, with no consideration of the actual furnace pressure.

To illustrate the control principles discussed, several schemes that have been or might be used under various conditions are discussed. (4)

Magnetic Test Data for Iron

Determination of the Magnetic Saturation Induction of Iron at Room Temperature." Raymond L. Sanford & Evert G. Bennett. *J. of Res. Nat. Bur. Standards,* Vol. 26, Jan. 1941, pp. 1-12. Research.

A determination of the magnetic saturation induction of iron at room temperature was made, using a modification of the Ewing isthmus method. This method produces magnetizing forces up to 10,000 oersteds with a moderate expenditure of power and without undue heating of the specimen.

Specimens were taken from several ingots of iron of exceptional purity prepared at the National Bureau of Standards. Corrections were made for the effect of the small amounts of impurities present, and care was taken to minimize systematic and accidental errors. The value found for pure iron at 25° C. assuming a density of 7.874 gm./cm.^{3} is 21.58 ± 0.01 kilogauss. WAT (4)

Refractive Index for Slag Control

"Iron Content and the Angle of Polarization of Chilled Surfaces of Open Hearth Slag." Michael Tenenbaum & T. L. Joseph (Univ. Minn.) *Blast Furnace Steel Plant,* Vol. 28, Dec. 1940, pp. 1157-1159. Research.

As it is well known that the presence of FeO in minerals and glasses increases their refractive index, a study was made of the relationship between iron content and refractive index of open hearth slags. The samples used were chilled rapidly by pouring the slag into a cast iron mold, and only the section adjacent to the mold was studied, as this edge was essentially single-phased.

Instead of measuring the index of refraction, the angle of polarization, the tangent of which is the refractive index, was measured and related to the iron content of the slag. A modified Fuess goniometer was used for measuring the angle of polarization. The illumination source was a 150-watt lamp. Light was first collimated and

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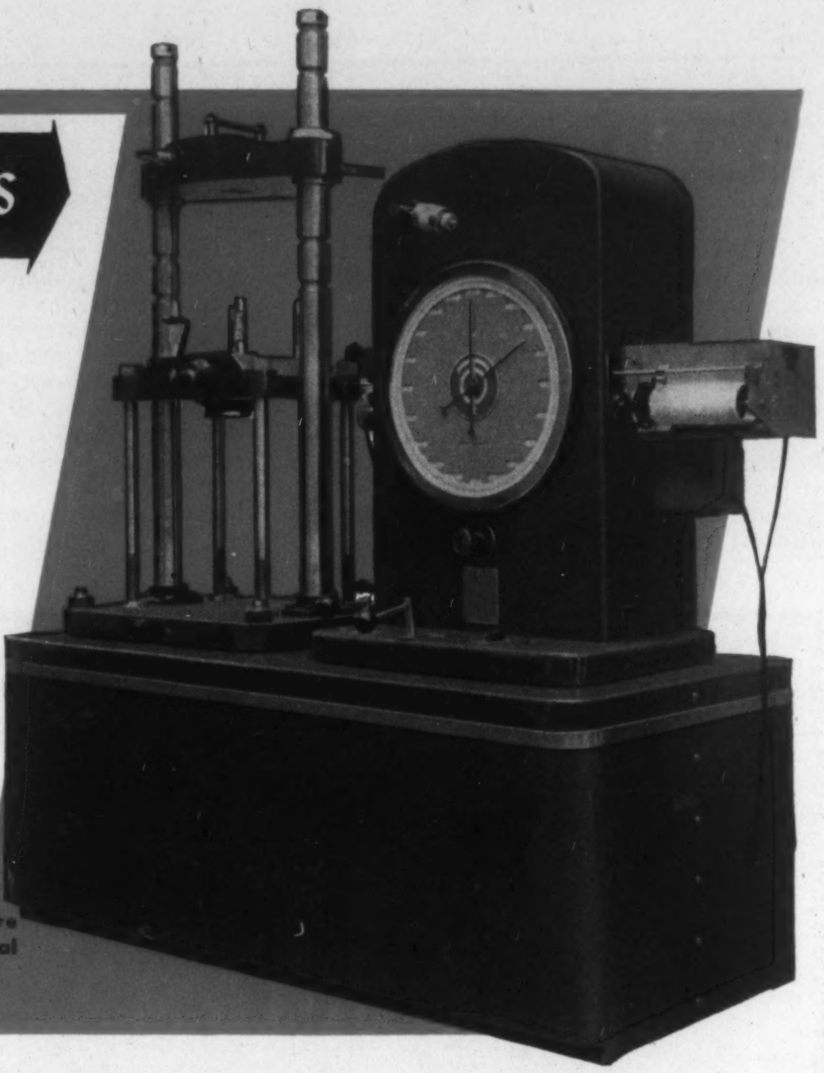

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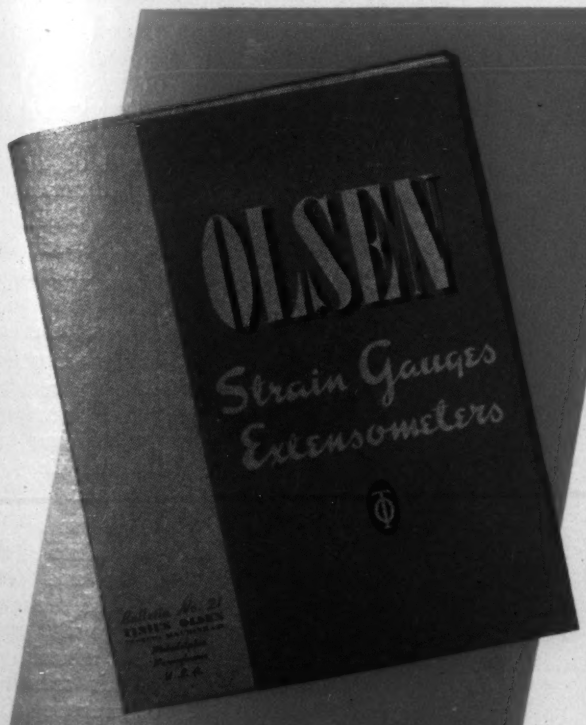

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after passing through a faint yellow filter was reflected from the polished slag surface. The reflected light then entered a polarizing eye-piece, the Nicol in which was set at right angles to the direction of polarization of the reflected light. After several trials, the angle of minimum light intensity was determined.

Slags were taken from industrial furnaces during the refining periods of typical basic open hearth heats. Part of the sample was used for chemical analysis, the bottom surface being used for measuring the angle of polarization. Slag pieces were ¼-½ in. square on their lower surfaces. Samples were polished dry, first on a coarse carborundum paper and finally on a 00 abrasive paper. The higher degree of polish facilitated the measurement. A minimum of material was removed by polishing.

The molar concentration of FeO in the slag was used for determining the relationship. Each mol of Fe_2O_3 was considered equivalent to 2 mols of FeO.

The results of numerous measurements indicate that the angle of polarization of the active portion of the slag increases as the FeO increases. This relationship is in accord with the general relation observed between iron content and refractive index of iron-bearing minerals. Deviations observed during this investigation are attributed to differences in the conditions of sampling and to the difficulty of ascertaining the exact composition of the chilled surface of the slag. Samples of slag taken immediately after large additions of ore gave a low angle of polarization for the iron content because all of the ore was not in solution. MS (4)

Spectrography of Aluminum Alloys

"An Investigation of Some Sources of Inaccuracy which May Arise in the Spectrographic Analysis of Aluminum Alloys." A. G. Quarrell & G. E. A. Bramley. *J. Inst. Metals,* Adv. Copy No. 891, 1941, 23 pp. Research.

It was proposed that a more accurate analysis of aluminum alloys could be made by combining solution and sparking than by sparking the metallic samples. It was found that errors of considerable magnitude could be introduced by variation in the photographic plates, and the magnitude of these errors is discussed in detail.

The most satisfactory methods of estimating the relative intensities of the lines used for analyses are considered, and it is concluded that the blackening characteristics of each plate should be determined with the aid of a mercury-vapor lamp. JLC (4)

Electrolytic Polishing of Aluminum Alloys for Metallographic Examination

"How to Electrolytically Polish Metals for Metallographic Examination." F. Keller (Aluminum Res. Labs.) *Iron Age,* Vol. 147, Jan. 9, 1941, pp. 23-26. Descriptive.

Advantages of electrolytic polishing are: Large areas can be prepared for visual inspection; low and high power examinations are possible; personal skill is eliminated; polished surfaces are free from flowed metal and have uniform etching characteristics; all scratches are removed; and final polishing can be done quickly and economically.

The disadvantages are: The method is not satisfactory for heterogeneous alloys because some constituents are dissolved and others are left in relief; different conditions are required for different alloys and tempers to obtain best results; and it is necessary to start with a smooth surface.

Electrolytic polishing results from the selective dissolution of elevated material on the metal surface; it is successful only when the rate of solution of the metal of the elevations is greater than that in the depressions. Mixtures of perchloric acid, acetic anhydride and water and of orthophosphoric acid and water are recommended for various metals. Electrolytic polishing produces its best results when the specimens are relatively pure metals or essentially solid solutions.

In polishing aluminum alloys, the results depend upon the type of microconstituents present. To obtain satisfactory results, specimens with initially plane surfaces should be used. Satisfactory polishing can be obtained on specimens finished on 3/0 or 4/0 metallographic emery paper.

The equipment used for aluminum alloys includes a potentiometer and suitable instruments for indicating voltage and current. Jacquet's perchloric acid, acetic anhydride and water solution will give good results with high purity aluminum and some aluminum alloys. This solution is, however, inconvenient to prepare and operating conditions are critical.

For several years aluminum has been polished electrolytically in the production of Alzak reflectors, and this (patented) process has been used successfully for polishing aluminum alloys for metallographic examination. The electrolyte used is a dilute aqueous solution of fluoboric (HBF_4) acid. This solution is inexpensive and safe to handle, and the operating conditions are much less critical than with Jacquet's solution. (Procedure details are not given.) VSP (4)

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books

Anodizing Aluminum

ANODIC OXIDATION OF ALUMINUM AND ITS ALLOYS. *By A. Jenny, translated by W. Lewis. Published by Chemical Publishing Co., Inc., New York, 1940. Cloth, 6¼ x 9 in., 231 pages. Price $6.50.*

A review (by the writer) of the original German edition of this book was published in the September, 1939, issue of METALS AND ALLOYS, page MA 562. Two sentences from that review, the opening and closing ones, may well be repeated here: "This book is a welcome addition to the limited number of reference books dealing with the 'anodizing' or anodic oxidation of aluminum. . . . A similar book in English would be very welcome."

Of the 14 chapters in the book, the first 7, under the heading "General Part," deal with the basic properties of metals, and particularly of aluminum, which underlie anodic oxidation. The properties discussed include general phenomena of dissolution of salts in water, behavior of metals towards liquids and towards gases, anodic processes during electrolysis, chemical properties of aluminum, the electrolytic properties of aluminum and other "valve" metals, and the anodic oxidation of aluminum.

The remaining 7 chapters, constituting the "Specific Part," are devoted to the more practical aspects of the process, such as the properties of aluminum oxide films, chemical processes during treatment, supervision of the bath, underlying causes of flaws in the film, commercial anodizing processes, methods for carrying out the "Eloxal" process and general surface treatment processes for aluminum. As stated in the previous review, the German term "Eloxal" (*El*ectrolytische *ox*ydierte *Al*uminium) was originally applied only to the method in which oxalic acid is used, but is now generally used for all processes of anodic oxidation.

A list of 145 British patents on anodic oxidation of aluminum has been appended by the translator.

Although the dearth of assembled and properly correlated technical information in English on anodizing is not nearly so acute as when the German edition of this book appeared—an accomplishment to be credited in large measure to Committee B-7, American Society for Testing Materials—the translation is still to be welcomed as a very useful addition to our technical book list. During present conditions it should be especially useful, since anodizing plays such an important rôle in our aircraft program.

—H. S. RAWDON

Plastics Catalog

MODERN PLASTICS CATALOG—1941. *Published by Breskin Publishing Corp., New York, 1941. Cloth, 9¼ x 12 in., 476 pages. Price $3.50.*

One has only to glance through this massive collection of materials, design and manufacturing data, both editorial and advertising, to realize the very great and growing extent to which plastics compete with metals for a variety of relatively small parts. Once upon a time metal and metal-form producers wishfully regarded the plastics threat as negligible, believing that the synthetic materials were too weak, too expensive and too "small-sized" ever to be of great competitive importance. But today, although total steel, aluminum or zinc production tonnage is hardly affected by plastics inroads, there must be scores of manufacturers of stampings and die castings who ruefully wish they still had those radio-set housing or camera-shell or office-machine part or wall-chime case or automobile-fitting jobs that they lost to plastic molders last year.

This catalog presents, among other things, all the photographic proof any skeptic could wish that plastics have fallen in step beside metals and that the advanced *metallurgical* design engineer must be giving *plastics* a lot of his attention. For all such engineers, and particularly for those designers-in-metal who may be forced to shift to plastics because they can't obtain the metal they want, this catalog offers a comprehensive record of design experience with plastics for many specific applications, plus a wealth of classified information on the production, compositions, physical properties, molding and fabricating, and applications of every type of plastic.

Among the most useful features are the "Plastics Properties Chart" and a directory and buyers guide covering plastics, raw materials, processing equipment, molders, fabricators, designers, trade names, etc.

—FRED. P. PETERS

Industrial Electrochemistry

INDUSTRIAL ELECTROCHEMISTRY. *By C. L. Mantell. Published by McGraw-Hill Book Co., New York, 1940. Cloth, 6½ x 9¼ in., 656 pages. Price $5.50.*

The electrochemical industries and processes have developed so rapidly within recent years that an up-to-date book is highly welcomed. The author has spared no pains in completely revising the subject matter and in this respect has had the valuable cooperation of the industry, as is duly acknowledged in the preface. The numerous photographs, line drawings and comprehensive tabulations add materially to the elucidation of the text.

The entire theoretical section has been rearranged and rewritten. Discussions of the historical aspects of the electrochemical industry have been included. As a text for graduate study in applied electrochemistry, the new book is invaluable.

—COLIN G. FINK

Pyrometry

TEMPERATURE MEASUREMENT. *By Robert L. Weber. Published by the author. Lithoprinted by Edwards Brothers, Inc., Ann Arbor, Mich., 1941. Cloth, 8½ x 10¾ in., 171 pages. Price $2.50.*

This book is described as presenting the substance of a course offered for Juniors by the Physics Department of the Pennsylvania State College.

In addition to temperature measurement and control, there are brief but sound treatments of heat transfer, calorimeters, thermal analysis, and thermodynamics. The author has collected, with figures and tables, the highlights of the recent literature of temperature measurement. This makes interesting reading, but sometimes results in over-emphasis of minor details and the omission of important topics.

The book is a satisfactory manual of practical pyrometry, useful both for reference and for general reading.

—H. W. RUSSELL

Other New Books

DANGERS AND HEALTH HAZARDS OF FIRE GASES. *By H. J. Davis, 3927 East Admiral Pl., Tulsa, Okla., 1941. Paper, 6 x 9 in., 12 pages. Price 25c.* Explains which materials give off toxic or inflammable products of combustion while burning, and suitable safeguards.

CHEMICAL ANALYSIS OF ALUMINUM. 2ND EDITION. *Published by Aluminum Co. of America, New Kensington, Pa., 1941. Spiral-ring binding, 5½ x 8¼ in., 120 pages. Price 50c.* Detailed methods are given for determining impurities, common alloying agents, and less common constituents in aluminum and its alloys, with special emphasis on methods of separation, solution, etc. prior to actual measurement.

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Papers presented at a Symposium held at New York, November 2, 3, and 4, 1939.

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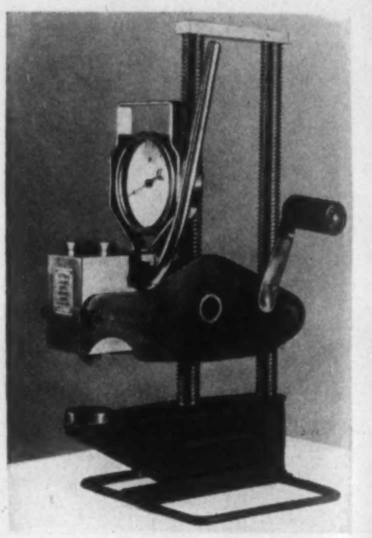

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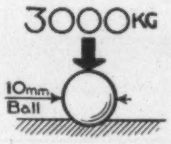

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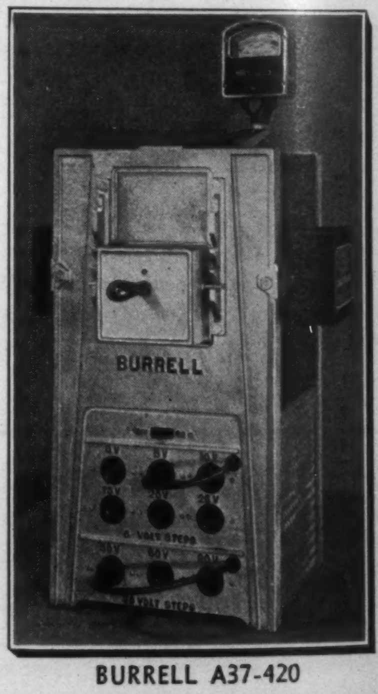

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trends

By Edwin F. Cone, Editor

Steel Casting Capacity

The trend in the rated capacity of the American steel foundry industry has steadily decreased in the last 10 yrs. at the rate of approximately 1,000 tons per month, according to authoritative information. The capacity as of Jan. 1, 1941, is put at about 110,000 net tons per month, or 1,320,000 net tons per year. Of this 900,000 tons, or nearly 70 per cent, is open-hearth and 420,000 tons is electric. There are some signs of increased capacity being developed to meet the demands of the Defense Program.

Blast Furnace Capacity

By an extensive program of blast furnace modernization and enlargement, the annual capacity of the country was increased about 2,000,000 tons in 1940 according to the American Iron and Steel Institute. No new furnaces were completed last year though several were under construction for probable completion in 1941. Capacity at the close of 1940 was 57,610,000 tons of pig iron and ferroalloys.

More Magnesium

The Dow Chemical Co.'s new plant at Freeport, Texas, for producing magnesium from seawater, already under production, is to be doubled in capacity. It will be financed by the Government.

The American Magnesium Corp., now a subsidiary of the Aluminum Co. of America, has expanded its possible output by increasing the capacity of its present plants and the acquisition of new plants.

Silver

Preliminary figures show that the total mine production of recoverable silver in the United States in 1940 was 8 per cent in excess of that of 1939. This trend is ascribed to the rise in the output of copper, zinc-lead, and lead ores.

Pistons for Automobiles

The placing of priorities on aluminum raises the question as to how automobile companies that use aluminum pistons will be effected—will they turn to cast iron or to a steel piston of the Ford type?

The interesting thing about this is that the tooling-up is different for ferrous and for aluminum pistons. When a change is made away from aluminum, it is likely to be quite permanent on account of the tooling. Incidentally, having to go away from aluminum will increase the call for new machine tools, stepping from one bottleneck into another.

High-Speed Steel

The present demand for high-speed steel is at an apparent yearly rate of more than 20,000 tons which contrasts with the previous peak record of 14,000 tons in 1929, says L. G. Firth, president of the Firth-Sterling Steel Co. This trend is pointed to as significant when it is recalled that improvements in tools and tooling since 1929 have resulted in a great deal more production per tool. One explanation offered for this increase is the rapid construction of new plants.

Consumption of Steel Scrap

A new record in domestic consumption of American iron and steel scrap was made in 1940—the estimated total is about 41,000,000 gross tons, according to the Institute of Scrap Iron and Steel, Inc. This is an increase of 26 per cent over the 32,434,000 tons melted in 1939, and exceeds the previous high record of 38,006,000 tons in 1937. The world war peak was 26,800,000 tons in 1917. Scrap is more and more a factor in iron and steel production.

Scrap

In order to provide an adequate supply of scrap iron and steel for the Defense Program, steps are being taken by the Institute of Scrap Iron and Steel, Inc., to find means of quickly bringing about 5,000,000 tons from remote areas. This is needed so that steel mills and foundries may operate at capacity. Current monthly rate of consumption is in excess of 4,000,000 gross tons, an all-time record, according to the secretary of the institute.

Iron and Steel Exports

Because of the war, the United States was called upon last year to send larger quantities of steel and iron to many parts of the world. This trend resulted in total exports exceeding any previous record by about 25 per cent. The total pig iron, steel and ferroalloys exports were 8,720,000 net tons last year—the previous high record was 7,049,000 tons in 1917.

Nearly 45 per cent of the total went to the United Kingdom. By contrast only 6 per cent of the 1939 outgo went there.

(Additional "Trends" on page 516)

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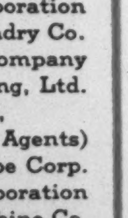

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trends

By Edwin F. Cone, Editor

Magnesium Castings

Expansion in magnesium mounts rapidly. The Ford Motor Co. is reported building a new foundry for magnesium castings at a cost of $800,000. It is to be incorporated into the present foundry building of the Rouge plant. Major use of the output, it is stated, will be for Ford production of Pratt & Whitney aircraft engines. About 110,000 lbs. of magnesium alloy castings a month is planned. There are to be 19 gas-fired melting furnaces varying in capacity from 100 to 2,000 lbs. each.

A Record in Magnesium

The largest output of primary magnesium in the history of the American industry was recorded in 1940. The total was 12,500,000 lbs., according to the Bureau of Mines. This was 87 per cent above the previous peak of 6,700,000 lbs. in 1939. Due to expansion in capacity, the 1941 production will probably exceed previous totals.

Cuts Machining Time

A special purpose 24-ton automatic machine for roughing out marine engine cylinders has been built by the machine tool industry. Operating on six cylinders at one time, this new unit cuts machining time per part from 4 hrs. to less than 35 min.

Tin

United States deliveries of tin increased decidedly last year over 1939 or 115,497 tons as compared with 71,896 tons. The 1938 deliveries were 50,660 tons. Deliveries during 1940, including tin acquired for the Emergency Reserve Stock, show an increase of nearly 61 per cent over 1939 deliveries.

New Equipment for Steel Industry

American steel companies plan to spend more than $282,000,000 for new production equipment during 1941, to meet expected expansion for defense and other purposes, according to the American Iron and Steel Institute. The amount budgeted for this year brings the sum spent or about to be spent by the industry for new equipment since Jan. 1, 1935, to a total of $390,000,000.

About 40 companies are contemplating the purchase of new heat-treating equipment this year.

Machine Tools

Production of machine tools for 1941 will total $750,000,000, an increase of $300,000,000 over 1940, says an announcement of the defense committee of the National Machine Tool Builders' Association. This is reported as $100,000,000 greater than earlier preliminary estimates made for 1941.

Steel Wages Higher

Wage rates in the steel industry are now higher than ever before, said T. M. Girdler in a recent address before the Engineers' Society of Western Pennsylvania in Pittsburgh. They are 32 per cent over the peak levels of 1929. Wage earners in the industry are earning almost as much in 40 hrs. per week as they earned in 1929 for 55 hrs.

Beryllium

Supplies of South American beryllium ore, which formerly went to Germany, are now available for importation into the United States. The result of this is an easing in prices and in the quantity available.

Beryllium-Nickel Alloys

Powder metallurgical methods have entered the beryllium-nickel alloy field, according to an announcement of Charles Hardy. Master alloys containing 10, 15 and 20 per cent of beryllium are said to be possible, using powders. Strip rolled from an alloy of beryllium and nickel containing 2 per cent of Be is reported to have a tensile strength of 240,000 lbs. per sq. in. and a Rockwell hardness, as rolled, of C 40.

Tin

Stocks of tin on hand in the United States are reported by the Bureau of Mines as sufficient to last over 15 months; measures are being taken to accumulate additional reserves.

(Other "Trends" on page 518)